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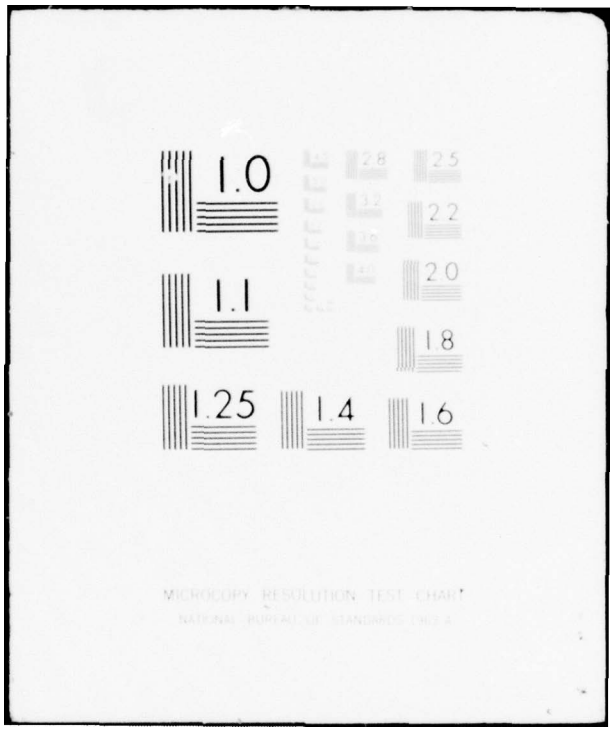
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COMPREHENSIVE SURVEY REPORT
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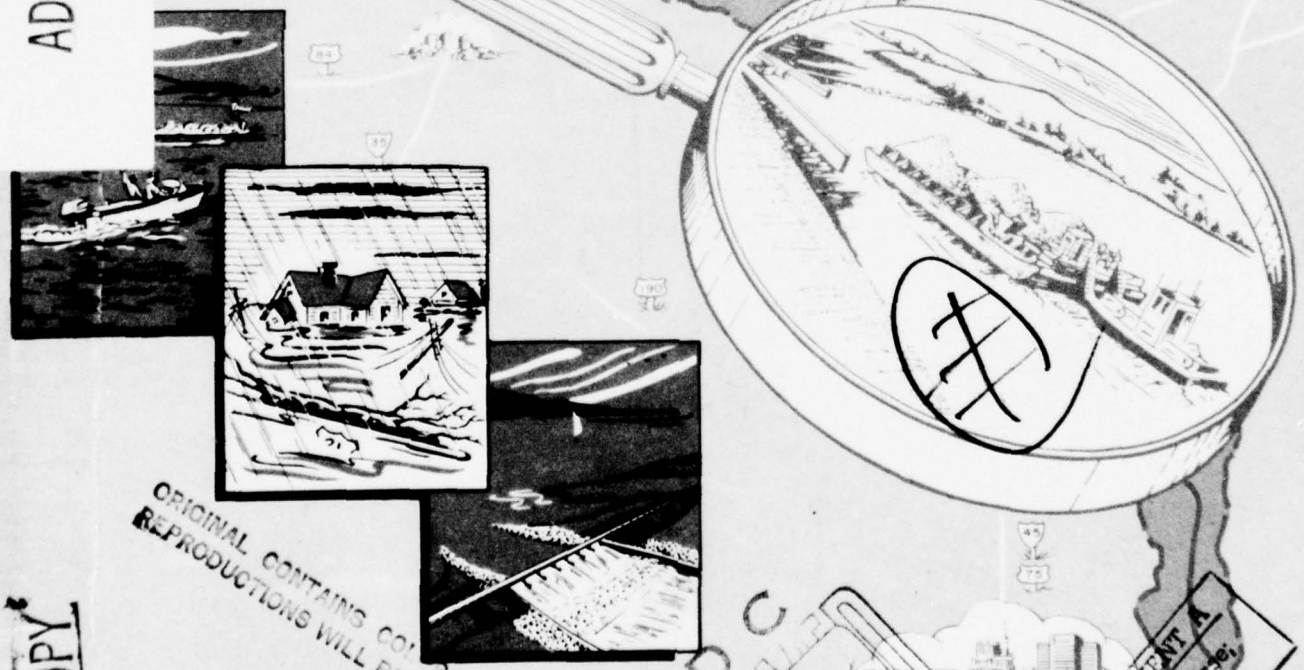

VOLUME 1

MAIN REPORT

U.S. ARMY/ENGINEER DISTRICTS
FORT WORTH AND GALVESTON, TEXAS
JUNE 1962

1st Ind

SUBJECT: Comprehensive Survey Report on Trinity River and Tributaries, Texas

United States Army Engineer Division, Southwestern, Dallas, Texas, September 19, 1962.

TO: Chief of Engineers, Department of the Army, Washington, D.C.

I concur in the conclusions and recommendations of the District Engineers, Fort Worth and Galveston Districts.

C. H. DUNN
Brigadier General, USA
Division Engineer

(11) June 62

(12) 132 p.

(6)

COMPREHENSIVE SURVEY REPORT

ON

TRINITY RIVER AND TRIBUTARIES, TEXAS.

Volume 1.

MAIN REPORT.

U. S. ARMY ENGINEER DISTRICTS
FORT WORTH AND GALVESTON
CORPS OF ENGINEERS
FORT WORTH AND GALVESTON, TEXAS

JUNE 1962

CONTENTS

COMPREHENSIVE SURVEY REPORT
ON
TRINITY RIVER AND TRIBUTARIES, TEXAS

This volume comprises "Main Report" of the subject report. The complete report consists of the following volumes:

COMPREHENSIVE SURVEY REPORT
ON
TRINITY RIVER AND TRIBUTARIES, TEXAS

SYLLABUS

The report presents a comprehensive plan of development for a balanced program to provide the best use or combination of uses of the water and related land resources of the Trinity River Basin, to meet all foreseeable short- and long-term needs, for the economic and social well being of all of the people.

The plan provides specific measures to satisfy the present and projected needs for water supply and water quality, flood protection, navigation, recreation, and fish and wildlife. The measures selected have been based on consideration of current and projected economic conditions. The projects recommended for authorization at this time consist of a multiple-purpose channel from the Houston Ship Channel to Fort Worth including a series of navigation locks and dams; four multiple-purpose reservoirs - Roanoke (including modification of Grapevine Reservoir), Aubrey (including modification of Garza-Little Elm Reservoir), Lakeview, and Tennessee Colony with a wildlife refuge; water quality control distribution facilities from Tennessee Colony Reservoir to the existing Benbrook Reservoir; and five local flood protection projects - West Fork Floodway, Elm Fork Floodway, Dallas Floodway Extension, Duck Creek Channel Improvement and Liberty Local Protection.

With respect to other purposes, land stabilization and drainage will be handled by existing programs and continuing Federal authorizations. Water requirements for irrigation potentialities of the basin are included in the plan as is water cooling requirement for thermal-electric power facilities which were determined to be the primary source of meeting future power needs of the area.

The total estimated construction cost of the projects recommended for authorization is $900,747,000 with an annual operation, maintenance and replacement cost of $8,447,000. The net Federal Government costs are $775,796,000 and $7,227,000, respectively. The total annual charges of the recommended projects are estimated at $38,910,000 and the total annual benefits are estimated at $62,420,000. The ratio of benefits to costs is 1.6.

COMPREHENSIVE SURVEY REPORT
ON
TRINITY RIVER AND TRIBUTARIES, TEXAS

MAIN REPORT

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CORPS OF ENGINEERS
FORT WORTH AND GALVESTON, TEXAS

June 30, 1962

SUBJECT: Comprehensive Survey Report on Trinity River and Tributaries, Texas.

THROUGH: Division Engineer
U. S. Army Engineer Division, Southwestern
Dallas, Texas

TO: Chief of Engineers
Department of the Army
Washington, D. C.

INTRODUCTION

1. SCOPE.- This report presents the results of a comprehensive investigation of the problems associated with the water and related land resources of the Trinity River Basin. It defines a comprehensive plan for use and control of the flows of the Trinity River and its tributaries to the practical extent required to assure the economic and social well-being of the people of the region, state, and nation. The plan presented herein serves as a guide to the development and control of the basin's water and related land resources and is based upon analysis of detailed technical data and investigations reported upon in the various appendixes to this report. The elements of the plan recommended for authorization at this time were developed in consonance with the overall plan taking into consideration current and projected conditions and economic justification.

2. PURPOSE OF THE INVESTIGATION.- The Trinity River Basin, encompassing 17,845 square miles, extends southward through the eastern half of Texas from the Red River Basin on the north to Trinity Bay on the south. The large population centers of Dallas and Fort Worth are located in the upper portion of the basin. Houston, the largest city in Texas and a vital factor in the development of the lower Trinity River Basin, is located just west of the basin near the coast. Owing largely to the fortunes of strategic location and certain chains of

subsequent events, a phenomenal growth of population, industrialization and expansion of the general economy has been experienced in recent years by each of these large cities. Dallas and Fort Worth largely developed as the financial and marketing hub of the upper Trinity and surrounding area with a more recent trend to a rapidly expanding industrial economy. Houston and its adjacent area has been characterized by rapid industrial growth and development as a distribution center. The growth of Houston has been accelerated to a marked degree by the establishment of deepdraft navigation in the area and connection with the inland waterway system of the nation. The rapid economic growth of the cities has been characterized also by the vigorous and progressive enterprise of the people, coupled with outstanding leadership in all fields of endeavor. These human resources added to such natural advantages as mild climate, abundant rainfall, and strategic location with respect to natural resources, rich agricultural areas and established transportation routes insure the continued rapid development of these cities and surrounding areas for many years.

3. Although possessing many of the same advantages, the middle portion of the Trinity River Basin has not matched the development tempo of the upper and lower parts and has remained largely agricultural in character. A complete explanation of the comparatively slow progress of the middle basin would undoubtedly involve factors other than lack of water resource development. It is certain, however, that the absence of such development and the periodic recurrence of devastating floods and severe droughts have been major deterrents to general development.

4. Generally speaking, the total water resources within the Trinity River Basin is adequate to supply the water needs for the foreseeable future. The water problems arise mostly from the extremes experienced through floods and droughts and the inadequacy of existing control measures to conserve and regulate the water for beneficial use. The rapid growth of the Dallas-Fort Worth complex in the upper basin, and the Houston complex some 300 miles to the south, as well as the relatively slow development of the middle basin area, have generated many social and economic problems which demand attention. A number of such problems are related to development of water resources, including water supply, flood control, water transportation, hydroelectric power generation, drainage, irrigation, recreation, fish and wildlife, water quality control and other related purposes. Recognizing the necessity for comprehensive and realistic planning, with consideration of both the present and future demands, officials of local government and other agencies concerned with development of the Trinity River Basin requested that this investigation be made.

5. ARRANGEMENT OF REPORT.- The following sections of this report contain the results, conclusions and recommendations of the Fort Worth and Galveston District Engineers, based upon analysis of detailed

technical data and investigations reported upon in the following appendixes to this report:

Appendix I - Project Formulation
Appendix II - Hydrology, Hydraulic Design, and Water Resources
Appendix III - Navigation and Navigation Economics
Appendix IV - Flood Control Economics
Appendix V - Recreation and Fish and Wildlife
Appendix VI - Cost Estimates, Geology, and Design Information
Appendix VII - Economic Base Study
Appendix VIII - Comments of Other Agencies
Appendix IX - Resolutions, Public Hearing, Prior Reports

6. HISTORY OF INVESTIGATIONS.- Records show that the lower 300 miles of the Trinity River carried considerable navigation during the latter half of the nineteenth century, although its use was severely restricted by wide variations in stream flow. In 1902 Congress authorized a 6-foot navigation project to Dallas to be obtained by channel improvement and a system of 37 locks and dams. Seven of the locks and dams and one auxiliary dam had been completed by 1917 in several disconnected reaches. The difficulty of maintaining open river navigation between the widely separated navigation pools, led the Congress to abandon the project in 1922, except for the 41-mile reach from the mouth of the river to Liberty, Texas.

7. The most recent general study of the Trinity River Basin was completed in 1941 and is published as House Document No. 403, 77th Congress, 1st Session. That study analyzed the needs of the basin for flood control, navigation, and allied purposes. The report presented and recommended adoption of a basic plan of improvement for the Trinity River and Tributaries for flood control, navigation, and water conservation. The plan included five dam and reservoir projects designated as Grapevine, Benbrook, Aubrey, Lavon and Little Elm, modification of Garza Dam and Reservoir and modification of the levees and floodways at Fort Worth and Dallas for flood control and water conservation, and a 9-foot navigation channel extending up the Trinity River, by means of locks and dams, from the Houston Ship Channel in Galveston Bay to Fort Worth. The report recommended construction of the improvements found justified by conditions existing at that time, consisting of Benbrook, Little Elm and Grapevine Reservoirs, modification of Garza Dam, improvement of the levees and floodways at Fort Worth and Dallas and the lower 49 miles of the navigation channel from the Houston Ship Channel to Liberty. Construction of the recommended elements of the plan and of Lavon Reservoir for flood control

was authorized by the River and Harbor Act of March 2, 1945. Subsequently, the Garza-Little Elm Reservoir, impounded by the Lewisville Dam, was constructed in lieu of the separate projects for modifying Garza Dam and constructing Little Elm and Aubrey Reservoirs. Based on several subsequent studies and reports, Congress has authorized additional modifications of the project to provide conservation storage in Lavon Reservoir, construction of the Navarro Mills Reservoir on Richland Creek and Bardwell Reservoir on Waxahachie Creek for flood control and water conservation, additional improvement of the Dallas and Fort Worth Floodways and a local flood protection unit along Big Fossil Creek at the city of Richland Hills. All of these improvements are in the upper portion of the river basin in the general vicinity of Dallas and Fort Worth. Two recent investigations of additional flood problems in this area have been made. Separate reports have been submitted which recommend extension of the Fort Worth Floodway to provide protection along a reach of the Clear Fork, channel and levee improvement along the East Fork below Forney Dam site and enlargement of Lavon Reservoir for additional water supply and recreation.

8. An urgent problem of salt water intrusion from Trinity Bay into irrigation water pumped from the lower Trinity River led to a recent investigation of a proposed barrier dam and reservoir near the river mouth. A report, published in 1961 as House Document No. 215, 87th Congress, 1st Session, recommends construction of the multiple-purpose Wallisville Reservoir, at about river mile 4, for navigation, water supply, salinity control, fish and wildlife and recreational purposes. The reservoir, which would have a normal pool elevation of 4 feet above mean sea level, is designed to operate as a unit for water conservation with the Livingston Reservoir, which is under construction at about river mile 129, by the City of Houston and the Trinity River Authority of Texas.

9. Under authorities contained in the Flood Control Act of 1944 and the Watershed Protection and Flood Prevention Act of 1954, the Soil Conservation Service of the U. S. Department of Agriculture has made investigations and plans for land treatment, flood prevention and the conservation, development, utilization and disposal of excess water on many small watersheds in the Trinity River Basin. The Soil Conservation Service has formulated plans for extensive land treatment measures and about 1,200 floodwater detention structures in the small watershed areas, of which 288 are now constructed.

10. The Trinity River Authority of Texas, an agency created and organized under laws of the State of Texas, in 1958 adopted a master plan for development of the water resources of the Trinity River for all beneficial purposes, including barge navigation from the Houston Ship Channel to Fort Worth, and for additional flood control improvements. The master plan was modified to some extent by a supplemental report adopted in 1960.

11. The U. S. Study Commission - Texas, created in 1958 by an Act of Congress, inventoried the land and water resources of all major river basins in Texas, excepting the Sabine, Red, and Rio Grande, and formulated a comprehensive plan to meet the projected water needs within the study area to the year 2010. The Commission plan, published in 1962, presents for each major river basin, including the Trinity, a plan for use of existing physical features and the addition of numerous proposed and potential improvements to conserve and control the available water resources and supply the projected demands for the basin. The development plans are phased into two parts; the first would provide for projected needs to the year 1975, while the second considers projected additional needs to the year 2010. The Study Commission plan was designed as a framework to present general principles and features of an overall approach to land and water development problems for the state. The plan contemplates that detailed studies and plans would be made by the various local, State, and Federal agencies, within their fields of interest and responsibility, to develop the various features of the Study Commission plan. The comprehensive plan proposed in this report is in full consonance with the plan developed by the U. S. Study Commission - Texas for development of water resources in Texas.

12. Many other agencies have made investigations of water problems in the Trinity River Basin. The Cities of Dallas, Fort Worth and Houston have made extensive investigations and plans, particularly in the problem of water supply and flood control. Various other cities, towns and drainage districts have been concerned with water supply and flood control problems. The Bureau of Reclamation, U. S. Department of the Interior, is investigating the water resources of Texas in connection with studies of a long-range plan for transporting water from water surplus river basins in East Texas to areas of water deficiency in the central and southern parts of the state. This investigation will include consideration of available water resources in the Trinity River Basin. The Select Committee on National Water Resources, United States Senate, compiled extensive inventory data on water resources in the United States. Data pertinent to the Trinity River were published in 1960 as a portion of Committee Print No. 4, 86th Congress, 2nd Session. The Texas Water Commission in 1961 published a report entitled, "A Plan for Meeting the 1980 Water Requirements of Texas" which includes data pertinent to the Trinity River Basin requirements.

13. All of the investigations and reports described above were carefully reviewed and considered in developing the comprehensive plan presented in this report. The plan is compatible in all respects with the major objectives of the plans developed by the various agencies concerned with water resources problems in the Trinity River Basin.

14. AUTHORITY FOR THIS INVESTIGATION.- This report has been prepared in response to five separate resolutions of Congressional Committees requesting review of the report published as House Document No. 403, 77th Congress, 1st Session and other reports and an item in

Section 112 of the Rivers and Harbors Act, approved July 3, 1958. The authorizing resolutions include three adopted by the Committee of Rivers and Harbors of the House of Representatives on March 31, 1944, February 28, 1945, and November 30, 1945; one adopted by the Committee on Public Works of the House of Representatives on August 6, 1948 and one adopted by the Committee on Public Works of the United States Senate on January 20, 1958. The several resolutions and the pertinent section of the Rivers and Harbors Act of 1958 are given in full in Appendix IX.

15. PUBLIC HEARINGS.- The views of interested parties concerning improvements for development and use of water resources of the Trinity River Basin in the interests of navigation, flood control, water conservation, water quality control, drainage, irrigation, hydroelectric power, fish and wildlife, recreation and other purposes were obtained at eleven public hearings held at various cities and towns in the basin between 1946 and 1958. Prior to development of the comprehensive plan, nine hearings were held in the upper part of the basin in the general vicinity of Dallas and Fort Worth. Two hearings were held at Liberty, Texas, in the lower basin. The date, location and purposes covered by each public hearing are shown in Appendix IX. A subsequent public meeting was held at Fort Worth, Texas, to present the features of a preliminary plan to local interests.

16. The Trinity River Authority of Texas, prior to preparation of its Master Plan in 1958, held public hearings for each of the seventeen counties within its jurisdiction to determine the views of local interests with respect to improvements desired. The U. S. Study Commission - Texas in 1960 held public meetings in Huntsville and Corsicana to obtain the estimates of local interests concerning present and future water requirements throughout the basin.

17. Improvements desired.- Through the several public hearings and subsequent conferences and correspondence, local interests have expressed desires for a Federal improvement project for the Trinity River Basin to include specifically the following features:

a. Reservoirs on the Trinity River and all major tributaries for flood control, water conservation, fish and wildlife conservation and recreation, and improvement of the river channel for flood control from Five Mile Creek to the mouth of the river.

b. A salt water barrier near the mouth of the river for water conservation and salinity control.

c. A waterway for barge navigation to extend up the Trinity River from the Houston Ship Channel to Fort Worth.

d. Extension of the Fort Worth Floodway upstream on the Clear Fork and downstream on the West Fork.

e. Floodways, including improved channels and levees, on the West Fork between Dallas and Fort Worth, on the Elm Fork from the mouth upstream to Grapevine and Garza-Little Elm Reservoirs, and on Duck Creek through the City of Garland.

f. Extension of the Dallas Floodway downstream to the lower ends of White Rock and Five Mile Creeks.

g. Enlargement of Lavon Reservoir and channel improvement below Lavon Reservoir on the East Fork, below the authorized Bardwell Reservoir on Waxahachie Creek, and on Town Branch through the City of Madisonville.

h. Rehabilitation of certain agricultural levees along the main stem, East Fork, Richland and Chambers Creeks.

i. Levees along the left bank of the Trinity River for flood protection to Liberty.

18. The Texas Water Commission has publicly expressed its policy that all additional flood control reservoirs should include the maximum practicable water storage for water conservation, fish and wildlife and recreation, and that the stored water be used to supplement the low-water flows of the river as necessary to meet the water requirements for municipal, industrial and irrigation uses and for water quality control.

19. Because of an urgent need for several of the desired improvements, separate investigations and reports have been made on certain specific problems prior to this report. A number of improvements have been authorized or recommended as a result of separate reports, as described in paragraphs 7 and 8. The problem on Town Branch at Madisonville has been considered in the development of a planned system of small watershed improvements by the Soil Conservation Service. The remaining specific problems indicated by the expressed desires of local interests were considered in development of the comprehensive plan presented in this report.

20. The public meeting held at Fort Worth, Texas on December 20, 1961, to present features of a preliminary plan being considered for inclusion in this report was attended by about 1,400 persons, of whom 90 persons spoke in favor of the proposed improvement and 4 spoke in opposition. A total of 320 briefs were submitted with 274

favoring the improvement, 35 in opposition, 6 noncommittal and 5 in opposition to the previously recommended Wallisville Reservoir Project. Proponents of the plan included local officials from practically all cities, towns and counties in the Trinity River Basin, many civic organizations, representatives of businesses and industries, landowners and interested individuals. Proponents were practically unanimous in endorsing the navigation aspects, as well as the water supply, flood control and other features of the plan. Representatives of the Texas Water Commission stated that the distinct possibility of navigation of the Trinity River from the Houston Ship Channel to Fort Worth had been recognized in its long range planning and that other elements of the comprehensive plan were not in conflict with its plans. Opposition to the plan principally was from the Texas Railroad Association and from civic organizations representing several cities in West Texas, outside of the Trinity River Basin. The opposition was concerned with the navigation aspects of the improvement plan and no objections were expressed to other features or purposes of the plan other than those of landowners affected by the Wallisville Reservoir. A digest of the record of the public meeting is given in Appendix IX.

BASIN DESCRIPTION

21. GENERAL LOCATION AND SIZE.- The Trinity River Basin lies in the eastern half of the State of Texas. It is bounded on the north by the Red River Basin, on the east by the Neches and Sabine River basins, and on the west and south by the Brazos and San Jacinto River basins. The basin, as shown on figure 1, with an overall length of about 360 miles and a maximum width in the headwaters of about 100 miles, extends generally along a northwest-southeast axis from Archer County on the northwest to Chambers County and Trinity Bay on the southeast. The total drainage area of the basin is 17,845 square miles.

22. PHYSICAL CHARACTERISTICS OF THE BASIN.- The Trinity River Basin is relatively long and narrow and is shaped somewhat like a funnel, with its maximum width being located in the headwaters region above Dallas and Fort Worth. The topography of the basin, as shown on figure 2, is generally that of a gently sloping plain, varying in elevation from about 1,250 feet above sea level in the headwaters to sea level at the mouth in Trinity Bay. In the upper reaches, the topography is generally rolling and broken, while below Fort Worth, the topography ranges from gently rolling to flat. Practically all of the basin is located in the geologically recent, Coastal Plain Physiographic Province, which has weathered considerably and is characterized by meandering and generally sluggish streams. The Trinity River Basin is predominantly an agricultural area with about one-fourth of its area in the middle basin in forests. Except for cultivated areas and fringes of timber along the stream courses, the remainder of the basin generally is covered with native grasses, with some brush in the northwestern portion.

23. STREAMS.- The main stem of the Trinity River is formed at Dallas by the confluence of the West Fork and the Elm Fork at river mile 505.5. Throughout its length, the Trinity River follows a tortuous course, meandering from one side of the valley to the other for a distance of about two times the length of the general axis of the valley. The West Fork, about 209 miles long, rises in Archer County, near the town of Olney, and flows southeastward about 156 miles to Fort Worth, where it is joined by the Clear Fork; thence, easterly about 53 miles to its junction with the Elm Fork at Dallas. The Elm Fork rises in Montague County and flows in a general southeasterly and southerly direction about 119 miles to join the West Fork and form the Trinity River at Dallas. The East Fork, about 112 miles long, rises in Grayson County northeast of Dallas and flows southward to the Trinity River about 20 miles southeast of Dallas. Below the East Fork at river mile 385.5, the Trinity River is joined by the Cedar Creek tributary system from the northeast and at mile 372.4 by the Richland Creek tributary system from the west. Below mile 372.4, numerous smaller tributary systems enter the river from both sides, with

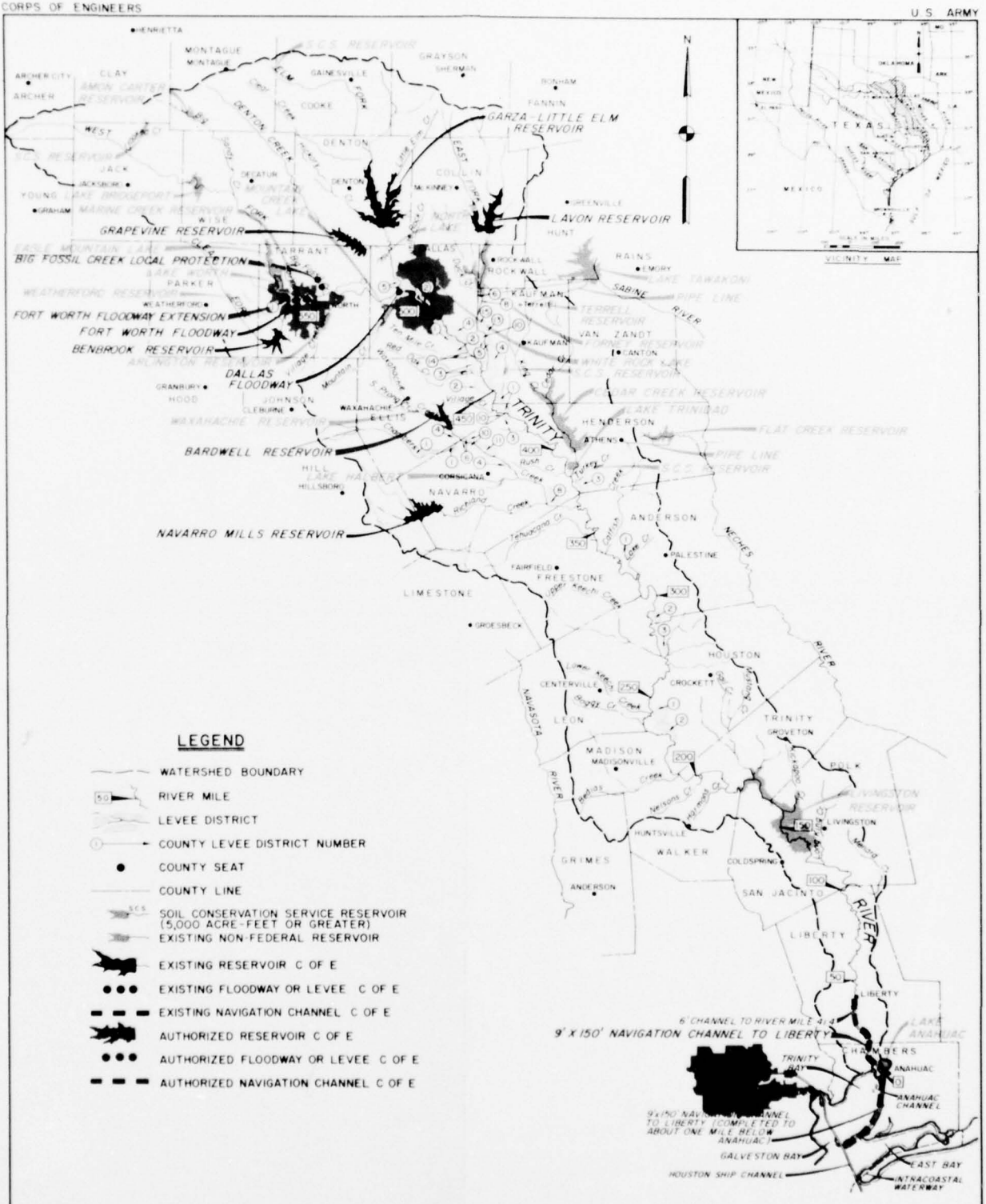


FIGURE 1

EXISTING AND AUTHORIZED IMPROVEMENTS

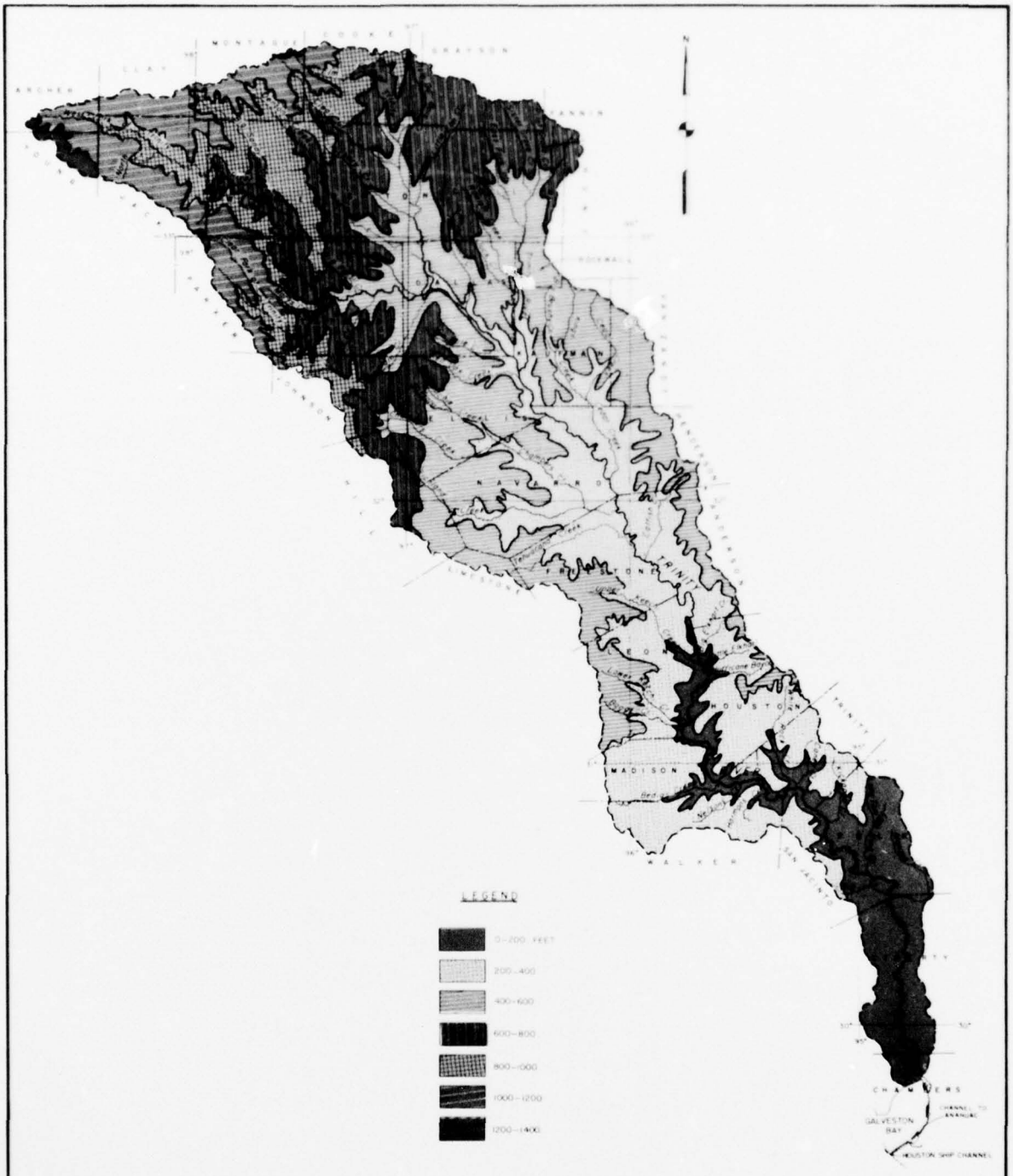


FIGURE 2

TOPOGRAPHIC MAP

the tributary lengths generally becoming shorter as the basin narrows to the south. The overall length of the river from its mouth in Trinity Bay to the headwater of the West Fork in Archer County is about 715 miles. Data pertinent to the Trinity River and its principal tributaries are shown in table 1 and scenes of the Trinity River channel are shown on figure 3.

TABLE 1

STREAMS OF TRINITY RIVER BASIN

Stream	Confluence with parent stream (mi above mouth)	Length (river miles)	Approximate total fall (feet)	Drainage area (sq mi)
Trinity River (incl West Fork)	-	715	1,250	17,845
West Fork	505.5	209	864	3,502
Clear Fork	558.7	70	775	531
Big Fossil Creek	542.7	21	296	75
Village Creek	533.8	33	458	184
Mountain Creek	507.8	37	463	305
Elm Fork	505.5	119	864	2,578
Denton Creek	18.4	102	685	719
Little Elm Creek	39.4	41	348	262
Clear Creek	50.5	55	650	354
White Rock Creek	493.1	42	386	138
East Fork	459.8	112	566	1,309
Duck Creek	31.0	22	270	45
Cedar Creek	385.5	92	374	1,072
Richland Creek	372.4	97	630	1,990
Chambers Creek	14.2	107	603	1,072
Tehuacana Creek	347.2	42	297	432
Catfish Creek	339.6	37	303	305
Upper Keechi Creek	272.8	40	352	512
Lower Keechi Creek	240.5	29	341	192
Bedias Creek	207.9	35	282	603
White Rock Creek	169.9	35	318	518
Long King Creek	117.5	31	258	214

24. CLIMATOLOGY.- The climate over the basin is generally mild with the distinctive features of a large range of annual and daily temperatures. In summer, the days are usually hot and the nights moderately warm. Generally, the winters are moderate and snowfall and sub-freezing temperatures are rare in the lower basin near the Gulf but are experienced occasionally during the winter season in the more northerly parts of the basin.

25. The mean annual temperature over the basin is about 66 degrees and varies from about 69 degrees in the lower part of the basin to about 64 degrees in the headwaters. Between July, the warmest month, and January, the coldest month, the mean monthly temperatures vary by about 35 degrees. Temperature extremes have ranged from about 112 degrees to minus 8 degrees in the northern part of the basin and from about 108 degrees to 8 degrees in the southern part.

TRINITY RIVER - BELOW DALLAS

TRINITY RIVER - VICINITY OF ROMAYOR, TEXAS

FIGURE 3

26. The mean annual precipitation over the basin averages about 38 inches and varies from about 27 inches in the northwestern extremity of the basin to about 51 inches at the lower end. An isohyetal pattern of mean annual precipitation over the basin is shown on figure 4. The annual runoff in the basin is influenced directly by the pattern of annual rainfall and increases generally from the headwaters to the mouth. The variation in annual runoff in various parts of the basin and a comparison with runoff for several selected floods of record are shown on figure 5.

27. Floods and droughts.- The statistics of mean annual precipitation, which are obtained by averaging the records over long periods of time, show that, on the whole, the Trinity River Basin receives a generous supply of fresh water through rainfall. The water problems, however, arise not from the averages but from the extremes. The history of the basin shows a recurring pattern of long to moderate droughts and periods of heavy rainfall, sometimes torrential in character. This is illustrated by the prolonged drought experienced throughout the basin during the years 1950-1957, followed by severe floods in 1957. The rainfall records for Fort Worth are typical for this period. Fort Worth has a normal annual rainfall of 33.7 inches. During the six full years, 1951 through 1956, the annual rainfall ranged from 18.6 inches to 25.2 inches and averaged 22.4 inches. The accumulated deficiency during the period was over 68 inches. The drought was broken by heavy rainfall which began in April 1957 and extended into the early part of June and totaled 28.8 inches. Similar heavy rainfall over much of the basin caused the largest volume of runoff during any similar period for which records are available. Grapevine, Benbrook and Garza-Little Elm Reservoirs had been completed during the drought years but only small amounts of water had been impounded. At the beginning of the rainfall period, storage was low in many of the older water conservation reservoirs in the upper basin. Had it not been for these circumstances, record breaking flood peak discharges would have occurred throughout the basin.

28. The drought periods cause serious shortages of water to the cities and towns which depend upon the river for municipal and industrial water supplies. Diminished water supplies also cause hardships throughout the rural areas of the basin. During the 1950-1957 drought, both Dallas and Fort Worth, as well as many smaller cities, were forced to curtail water use and seek temporary means of supplementing their water supplies. Dallas found it necessary to import low quality water from the Red River Basin as a temporary measure. On the other hand, during periods of heavy rainfall, vast quantities of unregulated water flow wastefully and often destructively down the river in floods and are lost in the Gulf of Mexico. If the Trinity River Basin is to reach its full potential of development, this destruction and waste cannot be tolerated. As the basin develops and population, industry and agriculture expand, more and more water will be needed and protection must be provided for the ever expanding developments. The answer lies in

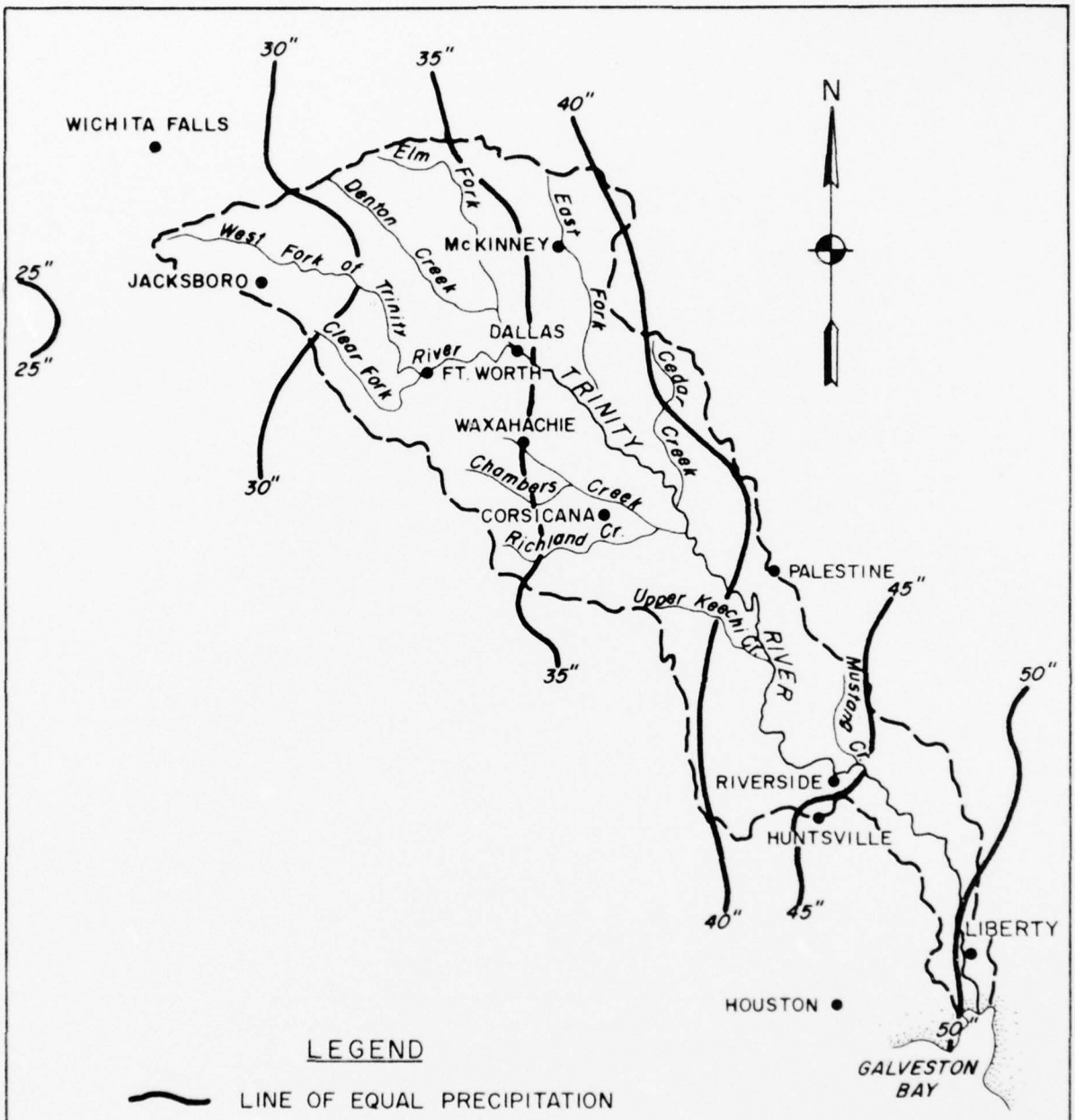


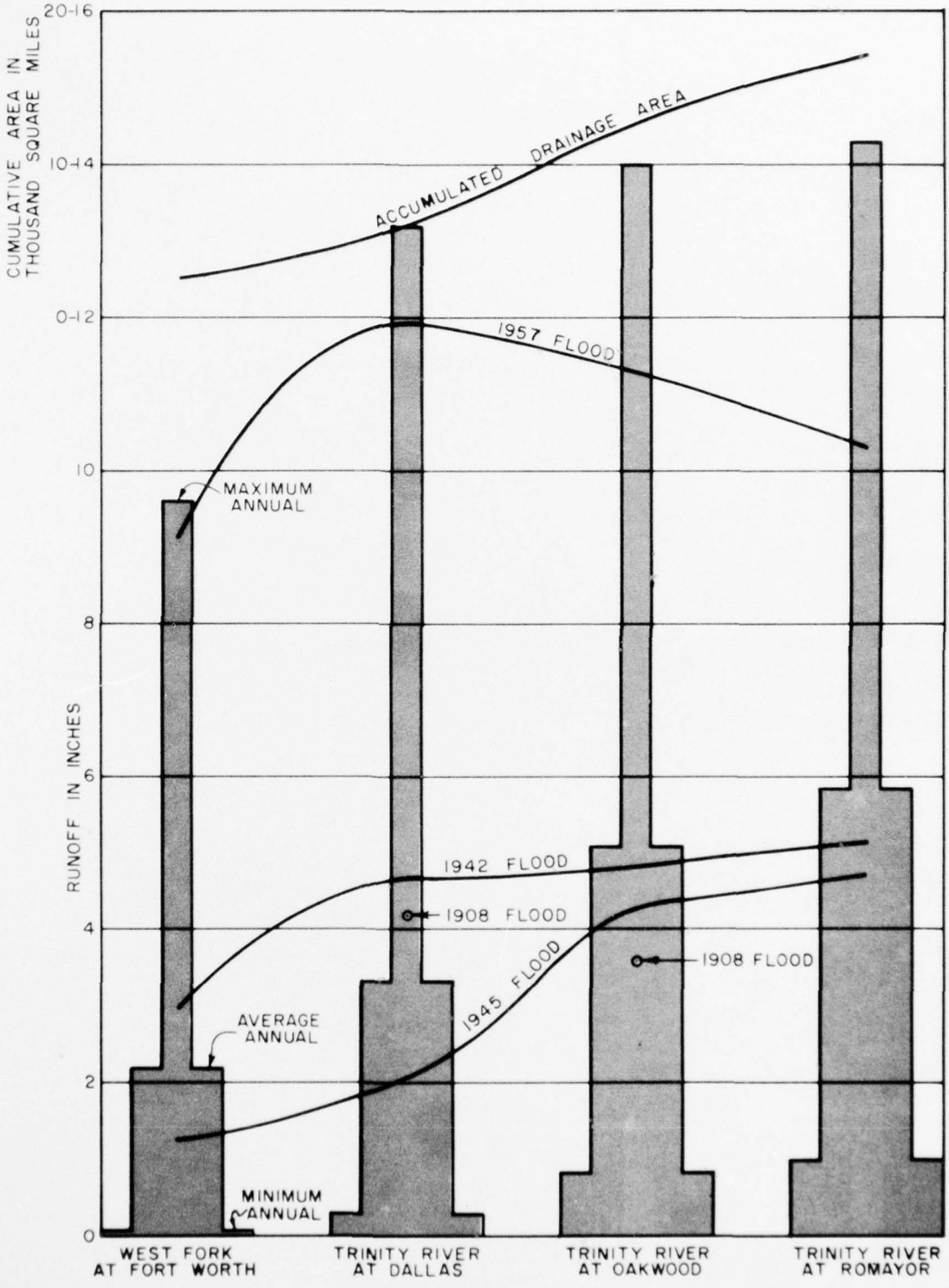
FIGURE 4

TRINITY RIVER

MEAN ANNUAL PRECIPITATION

SCALE IN MILES

0 20 40 60



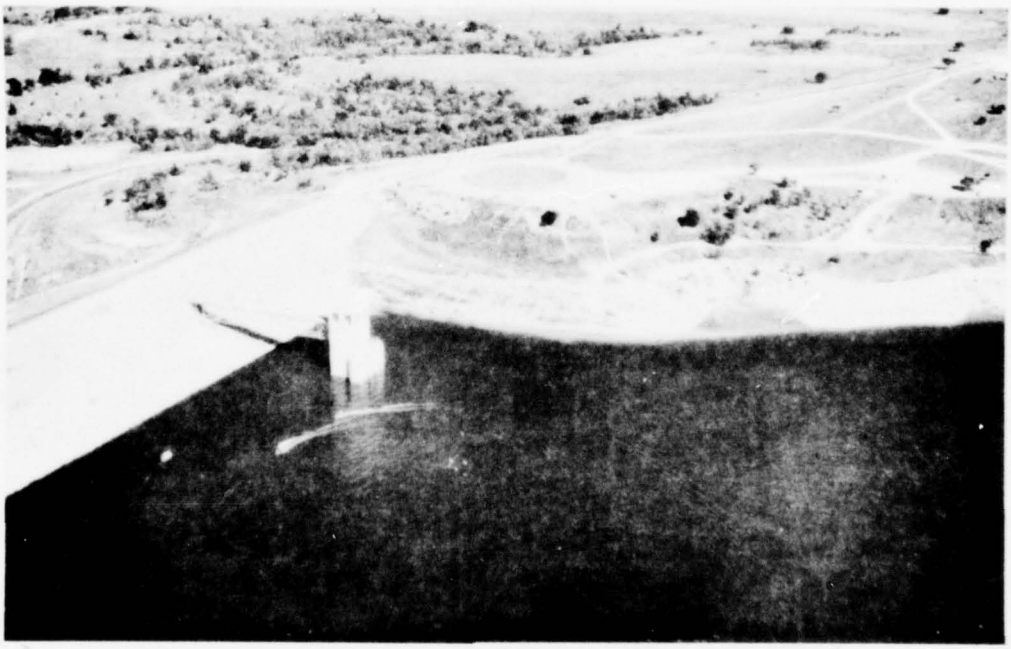
Notes:
All data observed except 1957 flood data and maximum annual data which have been corrected for reservoir storages.

FIGURE 5
TRINITY RIVER BASIN
RUNOFF DATA

controlling and regulating the river so that, to the maximum extent practicable, the flood waters can be stored and conserved for beneficial use, and providing facilities to assure protection against floods.

29. EXISTING IMPROVEMENTS.- The residents of the Trinity River Basin have for many years been cognizant of their many water problems as evidenced by the construction of the first major water supply reservoir, White Rock Lake, by the City of Dallas in 1911 and the organization of the first levee improvement district in 1909. Subsequent to those dates many facilities, both single and multiple-purpose, and both Federal and non-Federal, have been constructed in an attempt to cope with the ever increasing water problems of the basin. At the present time there are 24 major reservoirs, either operational, under construction or authorized, which contain conservation storage capacity and have individual total storage capacity of more than 5,000 acre-feet. Six of these reservoirs are Corps of Engineers projects which provide flood control storage. One of the 18 non-Federal reservoirs also provides storage specifically for flood control. The locations of these reservoirs are shown on figure 1 and data pertinent thereto are shown in tables 2 and 3. Scenes typical of projects constructed by the Corps of Engineers are shown on figure 6. The Soil Conservation Service has constructed four flood detention reservoirs with individual storage capacities greater than 5,000 acre-feet. In addition, the Soil Conservation Service has an extensive program underway in the basin for agricultural land treatment measures and a program for runoff and water flow retardation and soil erosion prevention. Prior to January 1961, the Soil Conservation Service had completed about 40 miles of channel improvements and constructed 288 floodwater retarding structures, which provide total storage capacity of 252,500 acre-feet, including 211,400 acre-feet for flood detention purposes. There are 79 smaller conservation reservoirs in the basin with individual total storage capacities of less than 5,000 acre-feet constructed by local interests. These reservoirs provide a total of about 41,000 acre-feet of conservation storage. In addition, for rural and agricultural purposes, there are about 66,500 farm ponds with an average storage capacity of about two acre-feet. About 40 active organized levee districts in the basin have concerned themselves with the water problems for about 50 years and presently maintain approximately 341 miles of levees to alleviate flooding in both rural and urban areas. The Corps of Engineers has constructed local flood protection projects in the Dallas-Fort Worth area and has been authorized to construct two additional local flood protection projects in the Fort Worth area. The Corps also has an existing and authorized navigation project in the lower Trinity River and in Trinity and Galveston Bays.

DALLAS FLOODWAY, FLOOD OF APRIL 1942



BENBROOK RESERVOIR AT CONSERVATION LEVEL

FIGURE 6

TYPICAL CORPS OF ENGINEERS PROJECTS IN THE TRINITY RIVER BASIN

TABLE 2

PERTINENT DATA
CORPS OF ENGINEERS RESERVOIRS

Item	Benbrook	Grapevine	Garza Little Elm	Lavon	Navarro Mills	Bardwell
Status	In operation	In operation	In operation	In operation	Under construction	Advance planning
Stream	Clear Fork	Denton Creek	Elm Fork	East Fork	Richland Cr.	Waxahachie Cr.
Location (river mi)	15.0	11.7	30.0	55.9	63.9	6.0
Drainage area (sq mi)	433	694	1658	777	316	171
Type of dam	Earth fill	Earth fill	Earth fill	Earth fill	Earth fill	Earth fill
Max. height of dam (feet above streambed)	130	137	125	69	82	68
Surface area-top of conservation pool (acres)	3,770	7,380	23,470	11,080	5,070	2,660
Storage capacity (acre-feet)						
Flood control	170,350 (1)	238,250	513,400	275,600	143,200	79,600
Conservation	72,500	161,250	436,000	100,000	53,200	29,500
Sediment	15,750	36,000	53,500	47,800	15,800	8,700
Total	258,600	435,500	1,002,900	423,400	212,200	117,800
Dependable yield (2)	6.5	18.1	86.0	35.5	18.1	4.2

(1) At elev. 724.0 (crest of uncontrolled spillway); 76,550 ac.-ft. at elev. 710.0 (notch crest)

(2) Million gallons per day based on maximum drought period of record and 2020 conditions of basin development.

TABLE 3

PERTINENT DATA
NON-FEDERAL RESERVOIRS
(With Capacities Greater Than 5000 Acre-Feet)

Name	Ownership	Location		Drainage area above dam (sq mi)	Storage capacity in acre-feet				Year constructed
		Stream	River mile		Sediment	Conservation	Flood-control	Total	
Amon Carter	City of Bowie	Big Sandy Cr.	31.0	103	5,100	14,800	0	19,900	1956
Bridgeport	Tarrant County WCID No. 1	West Fork	626.2	1114	37,700	233,200	0	270,900	1932
Eagle Mountain	Tarrant County WCID No. 1	West Fork	583.3	1974	39,100	143,500	0	182,600	1934
Lake Worth	City of Ft. Worth	West Fork	572.1	2069	2,100	31,600	0	33,700	1913
Marine Creek	Tarrant County WCID No. 1	Marine Cr.	4.7	10	450	3,350	11,600	15,400	1957
Weatherford	City of Weatherford	Clear Fork	39.8	106	6,300	13,100	0	19,400	1956
Arlington	City of Arlington	Village Creek	8.0	136	10,100	35,600	0	45,700	1957
Mountain Creek	Dallas Power & Light Co.	Mountain Cr.	4.1	289	20,000	4,200	0	24,200	1936
North Lake	Dallas Power & Light Co.	So. Fork, Grapevine Creek	0.5	2.3	1,100	16,000	0	17,100	1957
White Rock	City of Dallas	White Rock Creek	12.0	99	7,400	4,900	0	12,300	1911
Trinidad	Texas Power & Light Co.	(1)	- -	- -	0	6,200	0	6,200	1925
Livingston (2)	City of Houston and Trinity River Authority	Trinity River	129.2	16,606	51,600	1,698,400	0	1,750,000	(2)
Anahuac	Chambers Liberty Counties Navigation Dist.	(3)	- -	129	0	35,300	0	35,300	1953
Forney (2)	City of Dallas	East Fork	31.8	1074	24,000	466,000	0	490,000	(2)
Terrell	City of Terrell	Muddy Cedar Cr.	9.8	13	1,200	7,100	0	8,300	1956
Cedar Creek (2)	Tarrant County WCID No. 1	Cedar Creek	11.1	1013	70,900	608,000	0	678,900	(2)
Waxahachie	Ellis County WID No. 1	So. Prong, Waxahachie Cr.	0.5	31	2,100	11,400	0	13,500	1957
Halbert	City of Corsicana	Elm Creek	0.7	12	1,170	6,250	0	7,420	1924
					280,320	3,338,900	11,600	3,630,820	

Notes: (1) Off-channel reservoir, on left bank of Trinity River just upstream from mouth of Cedar Creek.

(2) Under construction.

(3) Off-channel reservoir, Turtle Bay.

REGIONAL ECONOMIC DEVELOPMENT

30. INTRODUCTION.- This study is concerned primarily with water problems and demands that can be solved by the construction of water resource improvements located within the Trinity River Basin. While the economy of the areas physically subject to flood damages and drainage problems has the greatest influence in planning solutions for these problems, the economy of additional areas outside of the basin affects planning for such purposes as municipal and industrial water supply, recreation, fish and wildlife, and navigation. The extent of the area varies with each purpose and is limited by the practical and economic aspects of the purpose served. The economy of a large segment of the area extending many miles beyond the Trinity River Basin influenced planning for extension of a navigable waterway to the Dallas-Fort Worth area because the agricultural products grown in the area, such as wheat, would be expected to move over the waterway in barges. Figure 7 shows the several economic areas which were taken into account in the formulation of the comprehensive plan for the Trinity River Basin. This figure shows that the economy of a total area comprising 148 counties in Texas and 30 counties in Oklahoma influenced the planning considerations for navigation. Similarly, the economy of a 46-county area in and adjacent to the Trinity Basin was taken into account in planning for water supply, recreation and fish and wildlife problems that might be solved by projects considered in this report. The economy of the area in and immediately adjacent to the flood plain was used in planning for flood control improvements. The area selected for the economic base study encompassed the areas considered for all purposes, covers 161,300 square miles and includes 183 counties in Texas and Oklahoma.

31. The lack of adequate control of the waters of the Trinity River Basin has resulted in a disheartening pattern of extremes from floods to droughts which have been dominating factors on the economy of the region. Floods not only have caused high damages to heavily populated metropolitan areas in the upper and lower regions of the basin but have also greatly retarded the economic development of the middle and lower sections of the basin. Damages to homes, farms and industries from floodwaters along the Trinity River and main tributaries average about 3 million dollars annually under present conditions of watershed improvement and development. Surface and ground water resources of the basin furnish about 306 and 72 million gallons, respectively, of water daily for use in homes, farms, offices, factories and other institutions. The surface waters also provide for recreation, rice irrigation in the adjacent coastal area and general small-scale irrigation throughout the entire basin, navigation in the lower reaches of the Trinity River and commercial fishing in Trinity Bay and marshlands adjacent to the Gulf. The unregulated flows and unintegrated

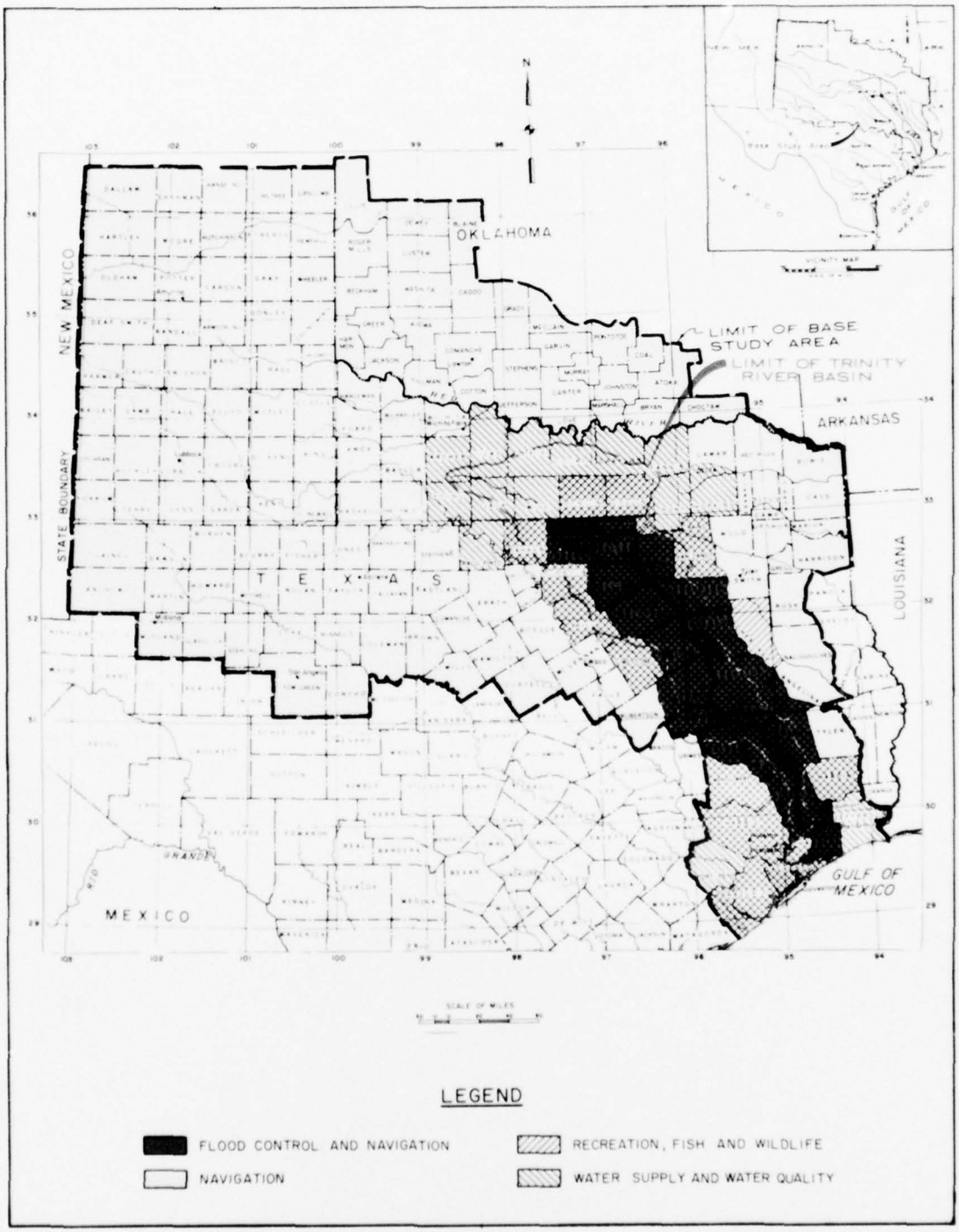


FIGURE 7. AREAS PERTINENT TO PROJECT PURPOSES

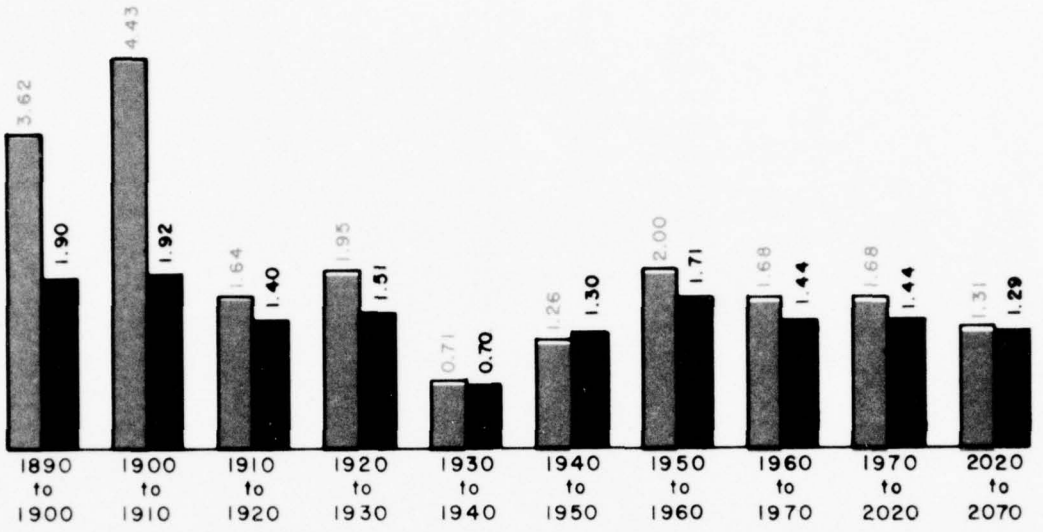
treatment of water problems have allowed the waters of the Trinity River, so urgently needed for the economy of the region, to waste to the Gulf and result in serious water shortages such as was experienced during the extended drought period of 1950-1957. Also, the waste effluent of rapidly growing municipal and industrial areas in the Dallas-Fort Worth complex has over-taxed the efficiency of the Trinity River to maintain a relatively "clean stream" of acceptable water quality.

32. POPULATION.- The Trinity River Basin population in 1960 was 1,895,000, of which about 80 percent is located in the Dallas-Fort Worth complex. The tremendous increase in population for Dallas and Tarrant Counties of about 500 percent over the past 50 years has been accompanied by a significant shift from rural to urban type economy in the upper basin. The middle area of the basin has remained rural in character and shows a decline in population for the last half century. However, it is anticipated with additional flood control measures and the construction of a waterway, the character of that area would change from predominantly agricultural to both rural and urban with resultant increase in population.

33. The metropolitan area of Houston is located just west of the Trinity River Basin near its mouth and has a large influence on water resource requirements for the lower basin. The population of Houston has shown an even more spectacular growth than the Dallas-Fort Worth area during the last 50 years and Houston is now the largest city in the State. The growth of the Houston industrial complex is continuing at a rapid rate and there is no doubt that this growth would extend into the lower Trinity Basin if the threat of flood damages were removed and other benefits of water resource regulation were made available.

34. The population of the base study area was 6,844,000 in 1960, or about 4 percent of the total United States population. A comparison of the growth rates given on figure 8 shows that the population of the study area has had an average annual rate of increase considerably greater than the national rate, except for the decade from 1940 to 1950. During the 70-year period from 1890 to 1960 the base study area's average annual population growth rate was 2.22 percent compared to the United States rate of 1.50 percent.

35. Projection of the basin population shows a rise from 1.9 million in 1960, to 2.4 million in 1970, to 5.9 million in 2020, and to 11.3 million in 2070. The population of the base study area is projected to increase from 6.8 million in 1960, to 8.1 million in 1970, to 18.6 million in 2020, and to 35.6 million in 2070. The projected average annual increase for the basin of 1.6 percent and for the base study area of 1.5 percent both are above the national average of 1.4 percent.



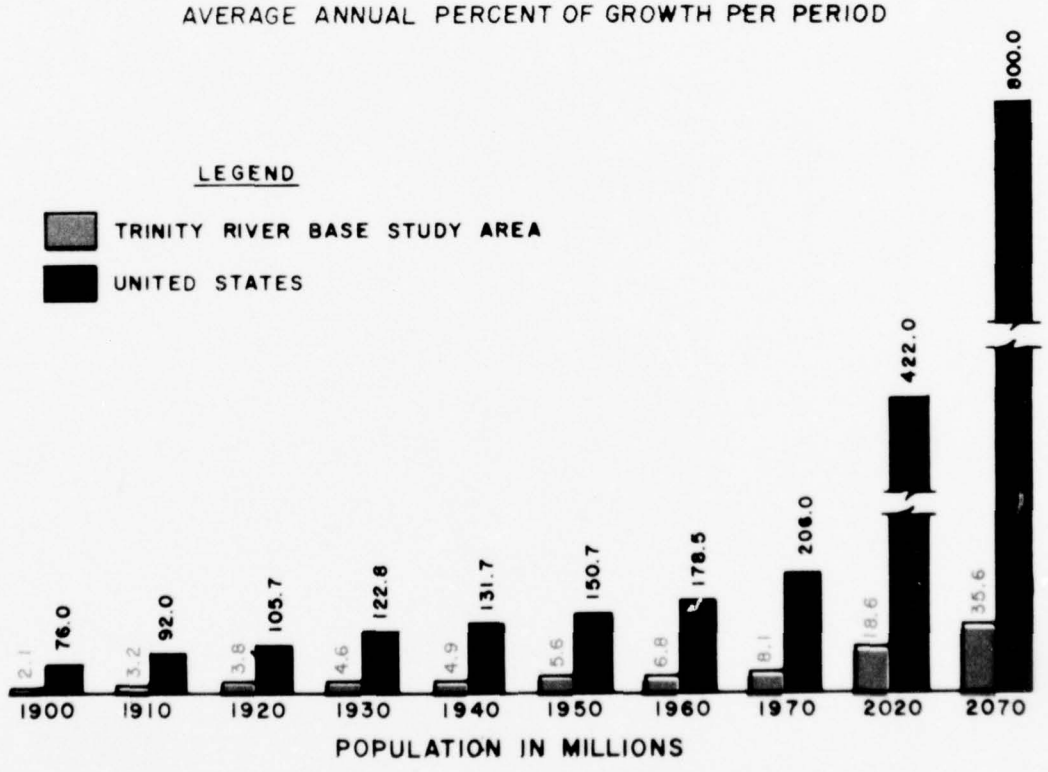


FIGURE 8

POPULATION GROWTH AND FUTURE PROJECTIONS

36. PERSONAL AND PER CAPITA INCOME.- Personal income is the most comprehensive available measure of economic activity and bears a close and generally constant relationship with the gross national product over the long run. At the national level it has been found that personal income exhibits the same 3 percent average annual growth rate that characterizes the long range trend of gross national product. In 1960, the 1.9 million residents of the basin and the 6.8 million residents of the base study area received $4.1 billion and $13.7 billion of personal income, respectively. On the basis of a per capita total this amounted to $2,170 for the basin and $2,015 for the base study area. While these amounts are slightly below the average for the nation as a whole, the annual rates of increase for personal income in the base study area have been greater than the annual increase in the national average during the period 1940-1960 as shown on figure 9.

37. MANUFACTURING.- The growth of manufacturing has been more rapid than that of any other economic development in the region and has been brought about by changing market demands, rapid technological improvements, increasing mobility of people and goods, and wartime emergencies. Many raw materials of the basin are adaptable to industrial needs but those coming from mining and agricultural activities have the biggest role in the area economy. The current trend is toward increased chemical processes in manufacturing as compared to the mechanical processes used in the past. The principal raw materials which are easily adaptable to use in the chemical industries are oil, gas, lignite, cotton, grain sorghums, and forest products.

38. The growing industrial development is evidenced in the value added by manufacturing, which, in the basin, jumped from $224 million in 1939 to $1.5 billion in 1960 and, in the base study area, rose from $841 million to $4.5 billion during the same period. The four largest industry groups in the region are chemical, petroleum, transportation equipment, and food products. The chemical industry is one of the newest and fastest growing and the abundance of raw materials available for petrochemical development indicates that it will continue to grow in the future. The petroleum refining and chemical manufacturing industries are concentrated in the Houston and Beaumont-Port Arthur area. The transportation vehicle and equipment industry is concentrated in the military aircraft factories in the Dallas-Fort Worth complex and constitutes 40 percent of the value added by manufacture for Dallas-Tarrant Counties. The production of food and kindred products is also one of the region's leading industries and some of the largest establishments are found in the larger population centers of Houston, Dallas, and Fort Worth.

39. Textile mill products, while not relatively important at the present time, give indications of becoming a large industry in the future. The production of wearing apparel and related products

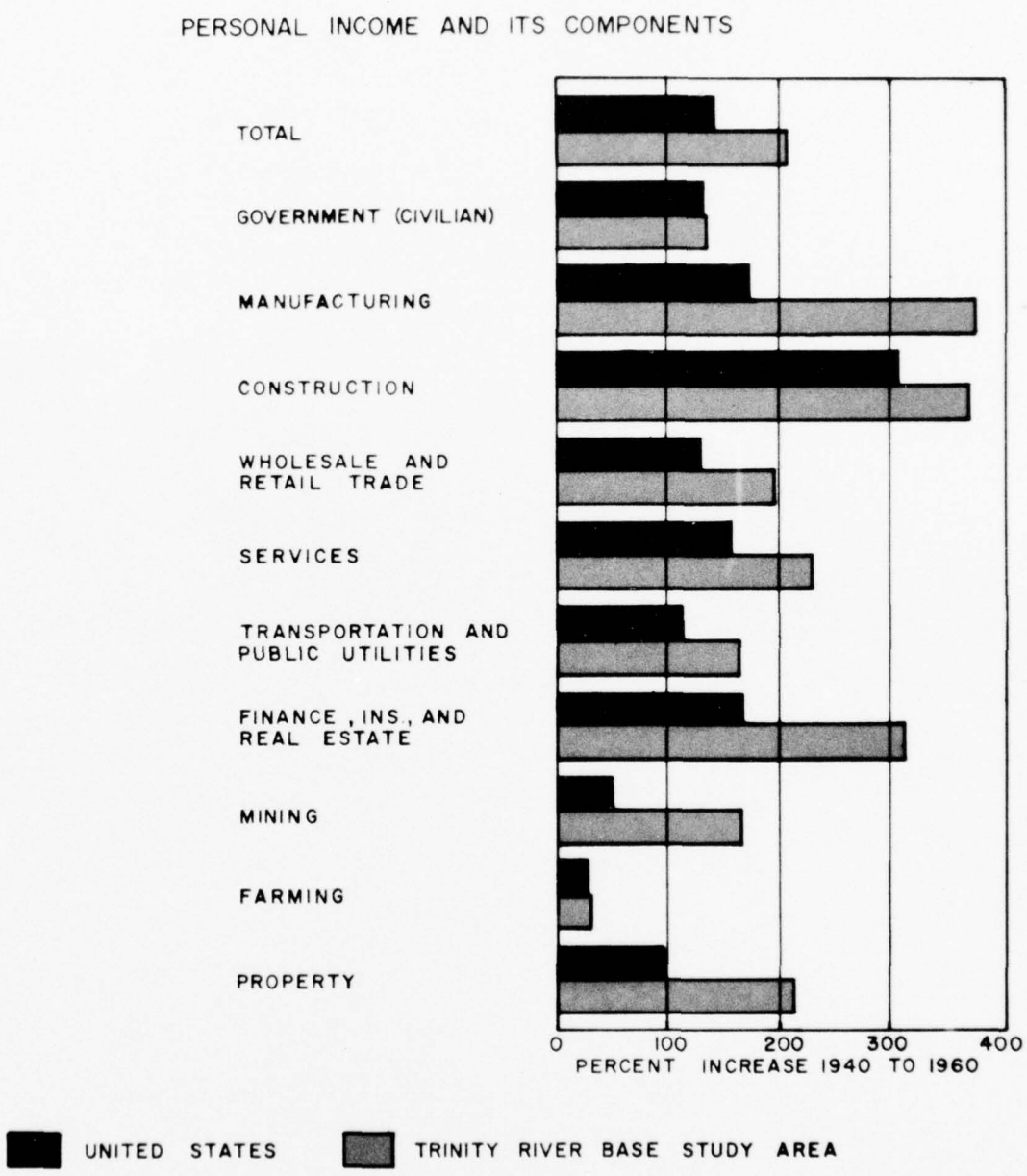


FIGURE 9

ECONOMIC TRENDS IN UNITED STATES AND TRINITY RIVER BASE STUDY AREA

has grown rapidly, with its greatest concentration in Dallas. The lumber and wood products industry is located principally in the East Texas forest area and is expected to grow rapidly on a sustained basis in the future due to good forest management practices. Printing and publishing is probably the most widely distributed industry in the region and Dallas is the leading city in the state in volume of business. Other significant industries include stone, clay, and glass products, leather and leather goods, primary metals, and machinery manufacturing.

40. The manufacturing establishments of the three largest cities, Houston, Dallas, and Fort Worth are such that manufacturers produce about 60 percent of the base study area's total value added. The construction of the Houston Ship Channel, which was completed about 1920, has made Houston one of the nation's major seaports and Texas' largest city. Today there are 108 industrial plants located in the Houston area with numerous others planned. Dallas and Fort Worth have numerous large industries for manufacturing airplanes, airmotive equipment, and heavy machinery. One important difference between the two large metropolitan complexes is that the Dallas-Fort Worth area lacks water transportation. The same opportunity for additional expansion and growth which developed in the Houston area would exist for the entire Trinity Basin if water transportation were made available. The 370 miles from Fort Worth to the Houston Ship Channel, as a navigable waterway for barges carrying bulky, heavy freight would attract numerous industries and act as the key to greater growth than inland Texas has ever experienced. A breakdown of the value added by manufacture during 1958 for various industries in Dallas, Fort Worth and Houston is given in figure 10.

41. POWER.- The growth of electric generating capacity in Texas is the fastest of any state in the nation. The tremendous increase in power production within the base study area is evidenced by the increase from 1.7 billion kilowatt hours in 1937 to an estimated 14.4 billion kilowatt hours in 1960 which is a total increase of about 750 percent. Comparable figures for the United States show an expansion from 180 billion kilowatt hours to 850 billion kilowatt hours in 1960 or a total increase of 370 percent.

42. AGRICULTURE.- Although rapid industrialization is taking place, agriculture is still of major importance, contributing substantially to the national production and economy. Farms, ranches, and woodlands occupy 88,372,000 acres, or about 138,100 square miles of the base study area. Total cropland is slightly over 32,000,000 acres of which 14 percent is irrigated. Figure 11 gives the breakdown of agricultural land use within the base study area.

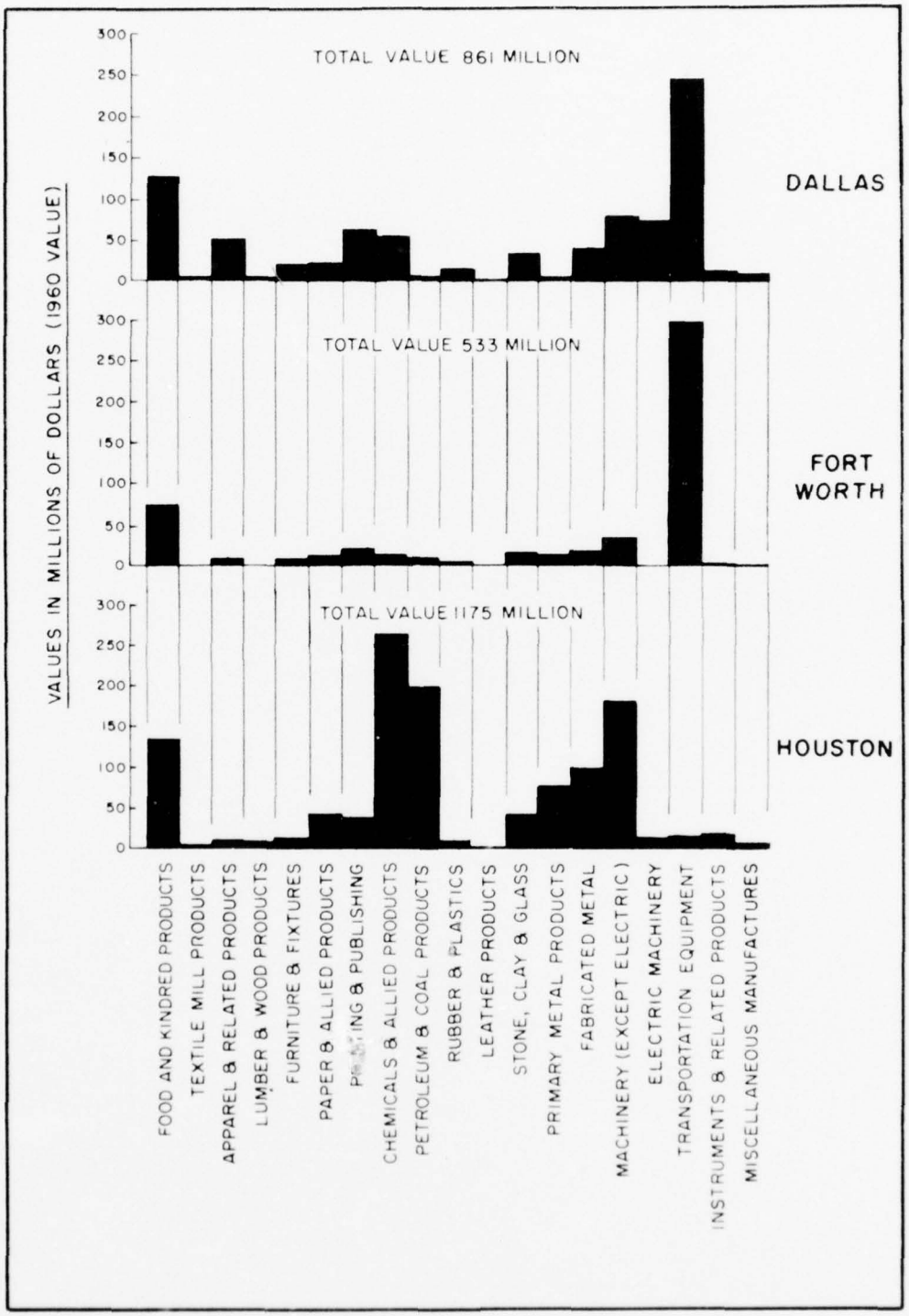


FIGURE 10. VALUE ADDED BY MANUFACTURE IN 1958
DALLAS, FORT WORTH, HOUSTON

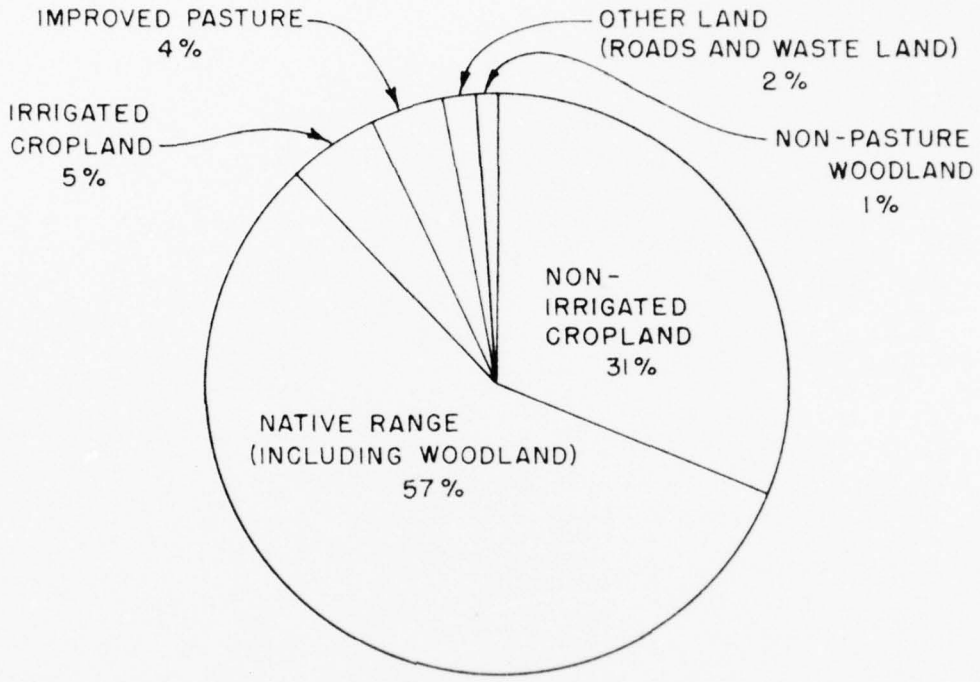


FIGURE 11

TRINITY RIVER BASE STUDY AREA AGRICULTURAL LAND USE
88,372,000 ACRES

43. A wide range of climatic and soil conditions provides an environment favorable for the production of most of the economically important crops and livestock. About 3.4 million bales of cotton, representing almost one-quarter of the Nation's cotton, is produced in the study area. Grain sorghum is grown in large quantities and production within the base study area represents 37 percent of the United States total. Large amounts of wheat grown in the Texas and Oklahoma areas lying north and west of the basin move to the Dallas-Fort Worth area and southward to the Gulf coast ports for export. Other important crops include rice, oats, and vegetables. Cattle raising is the main livestock enterprise, but sheep and goats are also raised in large quantities. The value of farm production in the base study area in 1959 and the production in the base study area as a percent of the United States production are given in figure 12.

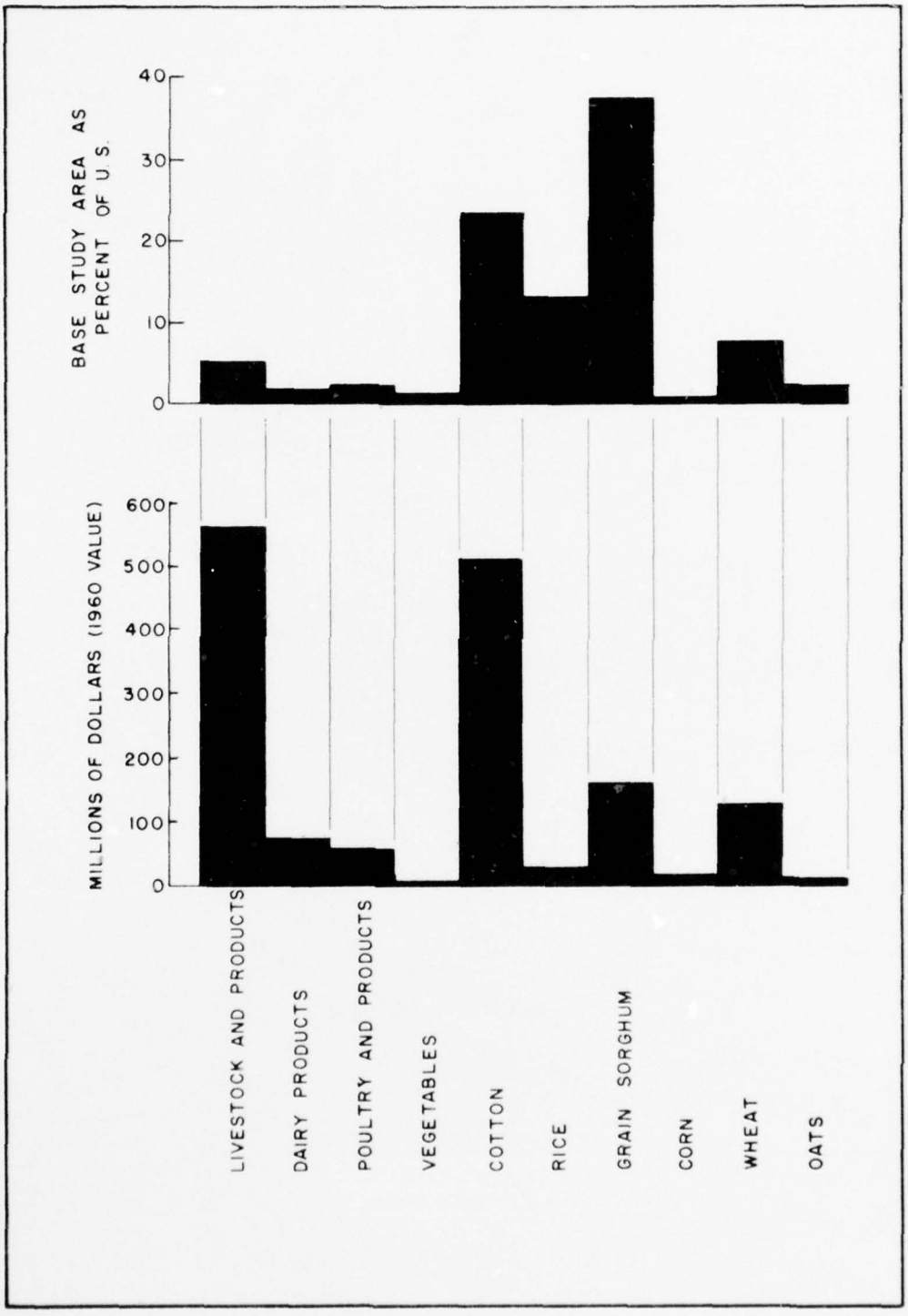


FIGURE 12

VALUE OF FARM PRODUCTION IN THE BASE STUDY AREA - 1959

44. TRANSPORTATION.- The urbanization and growth of any area is directly dependent upon adequate and economical transportation. Without transportation, the growth of cities and the concentration of industry and manufacturing would be limited by the ability to derive a food supply for inhabitants and all other basic necessities for the general economy from the immediate locality. The cost of transportation is an integral part of the cost of production and the free exchange of goods and products can be effected only to the extent that efficient and economical transportation is available.

45. There are five significant modes of transport for intercity freight in the United States. Statistics show that, in 1958, railroads carried about 46 percent of all intercity freight, with the remainder being divided among highways, 21 percent; inland waterways, 16 percent; oil pipelines, 17 percent; and airlines, a small fraction of one percent. Based on the forecasted growth of the gross national product and a continuation of the present relationship between the gross national product and intercity freight traffic, it has been estimated that, by 1980, the United States will need a transportation system having a capacity, in ton-miles of about double the nation's present freight traffic. By the year 2000, freight traffic is estimated to be at least four times the present volume.

46. Although, at this time, railroads generally are operating at less than physical capacity, the emergency demands of World War II strained the freight-carrying capacity of the railroads to the utmost. Since World War II, the use of improved rolling stock and more efficient operating practices have increased the total freight carrying capacity of the main lines and there is little doubt that at this time, the railroads could absorb a considerable increase in freight volume with little increase in track mileage. However, with the projected future demands for intercity transportation, it is not likely that this condition, in general, will endure beyond the next few years.

47. The Trinity River Basin and adjacent areas are served by the facilities of seven major railroad systems, which provide a network pattern of main lines with feeder and distributor branches throughout the eastern and southern parts of Texas. The north-south main lines provide connections between the central transcontinental routes of the Union Pacific system and the southern transcontinental routes of the Southern Pacific and Atchison, Topeka and Santa Fe systems. Generally, the north-south main lines extend southward from St. Louis, Kansas City, Wichita and Denver, converge on the Dallas-Fort Worth area and, following various routes through central and eastern Texas, continue southward to Houston and Galveston and southwestward to Waco, Austin, San Antonio and the Rio Grande Valley. The north-south lines between the Dallas-Fort Worth and Houston areas do not closely parallel the Trinity River and, in the middle basin area, are located somewhat to the east and west of the basin proper.

48. A network of improved highways provides facilities for motor transport to most of the Trinity River Basin. However, as with the rail lines, the main north-south highways skirt the middle basin area without extending deeply into the basin proper. The highway facilities are being augmented at this time by construction of an elaborate system of modern highways, through the Interstate Highway program. As with the railroads, motor freight carriers could move larger amounts of freight than they are now moving, although the joint use of the highways by motor trucks and private automobiles presents serious problems in traffic control and highway construction and maintenance as the total volume of traffic increases.

49. Motor freight traffic undoubtedly will continue to increase; however, this means of transportation is not truly competitive for mass shipments of bulk commodities at lowest cost. The prime advantage of truck transport lies in the rapid and flexible movement of small units of individual shipments. The low ratio of load to power required for movement results in a high unit cost of transportation and precludes effective competition in the market for mass transportation of bulky low-value items.

50. Air freight is of little significance in the overall pattern of intercity freight transportation. The advantage of air freight lies in ultra-rapid movement of small, lightweight items. The movement of freight by air will continue to increase, perhaps at a greater rate than by other modes of transport. However, it is equally certain that the limitations of size, weight and high cost will preclude the movement of any significant portion of the total intercity freight by air.

51. In analyzing the overall transportation requirements, pipelines can be considered only to the extent that movement of liquid or gaseous commodities are involved. An extensive network of pipelines extends in and through the Trinity River Basin. The pipelines principally are for gathering and distributing natural gas or for gathering and transporting crude oil to refining centers and shipping terminals along the Gulf Coast. Some of the pipelines are used for moving liquid refined products from refineries to distribution centers. Pipelines will remain an important factor in transportation of liquid petroleum commodities; however, being limited to the movement of liquids, they can be assigned only a small field of application in satisfying the general mass transportation demands.

52. Demand for mass transportation.- For the most part, the demand for low-cost, mass transportation must be met either by rail or waterway transport. Each of these means has its inherent advantages and, where both can be provided, together offer the most efficient and economical mass transportation facilities known today. Railroad

transport offers rapid service at relatively low cost for a wide range of freight. It is relatively free of topographical limitations and, with the extensive rail network already in existence, serves thousands of different points throughout the nation. Comparatively small units of freight can be efficiently handled. However, for movement of large volumes of freight at extremely low cost, waterway transportation is clearly superior. No other form of transportation can approach its high ratio of load to power required for movement, nor its low cost per ton for movement of those commodities for which it is suited. Many types of industry are dependent on mass transportation at the lowest possible cost, and it is a well demonstrated fact that such industries will concentrate in localities having water transportation. This is illustrated by the tremendous industrial developments in recent years along the modern inland waterways of the Ohio River Valley, the lower Mississippi Valley and Gulf Intracoastal and connecting waterways in Louisiana and Texas. Such industrial developments lead to a general expansion of the economy in the surrounding areas and generate additional traffic for the waterway, railroad and highway truck transport. It is significant that virtually all major industrial areas of the United States are served by water transportation. With a population in 1960 of about 1,657,000, the Dallas-Fort Worth complex is the largest urban-industrial area in the United States that is not located on a navigable waterway.

53. ROLE OF NATURAL RESOURCES IN THE ECONOMY.- The change in the economy of the region surrounding the Trinity River from frontier subsistence to a growing urban-industrial complex has occurred largely since the Reconstruction period following the Civil War and is due, in large part, to the vast and varied resources of the region. The first of several economic stages was the colonial era of cotton and cattle, which was an energetic period of rapidly advancing frontier, gathering momentum with the westward push of the railroads. The second stage, that of forest and mineral exploitation, began near the turn of the century and continued a rapid increase until about 1940. This middle period of development of the natural resources augmented by World War II brought about the next major period of advancement, that of industrialization and urbanization, which is of utmost importance today. The relationship that exists between the natural resources and the continued economic growth and development of the region is described in subsequent paragraphs.

54. Timber.- Most of the heavily timbered areas in the region are located in 43 counties in eastern Texas and 17 counties in eastern Oklahoma, of which three of the Oklahoma counties and 34 of the Texas counties are in the base study area. Timber interests first undertook large-scale operations in forest exploitation toward the end of the 19th century and by 1907, more than two billion board feet were being removed annually, mainly from the East Texas forest area. The tremendous

lumbering operations during the early part of this century caused rapid depletion of the forest reserves and brought about the establishment of a conservation program in 1915 by the Texas State Department of Forestry (later changed to Texas Forest Service). The conservation program assured adequate forest reserves and during the period from 1915 to 1958 lumber production for the State of Texas averaged a billion board feet. Today timber is being grown more rapidly in the East Texas Forest Region than it is being harvested, and has been established as an important permanent resource. The extensive East Texas Forest Region covers the lower and a portion of the middle Trinity River Basin as shown on figure 13. The commercial forest land in the base study area and the amount of growing stock and saw timber volume is given in table 4.

TABLE 4

COMMERCIAL FORESTS IN TRINITY RIVER BASE STUDY AREA
1953-1956

Item	Unit	TEXAS		OKLAHOMA	
		34-County Total	Percent of State Total	3-County Total	Percent of State Total
Land area	acre	17,935,500	10.6	1,473,300	3.3
Commercial forest	acre	9,471,300	77 8	744,000	13.2
Growing stock:					
Softwood	(1)	34,351,200	71.4	25,200	0.4
Hardwood	(1)	32,841,600	78.0	1,950,000	19.8
All species	(1)	67,192,800		1,975,200	
Saw timber volume:					
Softwood	(1)	12,576,500	71.6	7,800	0.4
Hardwood	(1)	7,341,900	75.9	414,900	20.5
All species	(1)	19,918,400	73.1	422,700	10.5

(1) Thousand board feet.

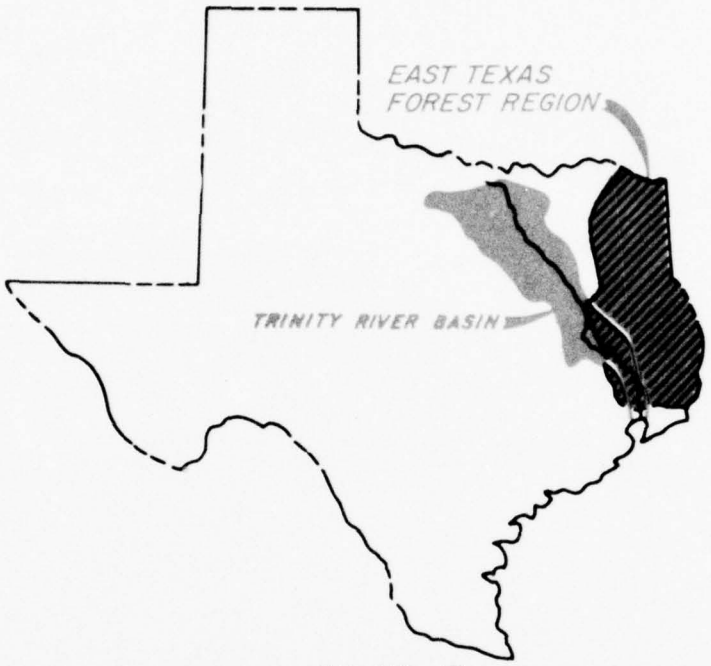


FIGURE 13
EAST TEXAS FOREST REGION

55. Minerals.- About 30 different minerals are produced on a commercial scale in Texas and Oklahoma, most of which are found in the basin. However, the production of crude petroleum and natural gas overshadows all other minerals in importance. The first commercial petroleum production of importance in Texas came from discovery of oil at Corsicana in 1894. Since then oil exploration has expanded rapidly throughout the Southwest. Texas currently produces about 40 percent of the total production of crude oil in the United States as shown on figure 14. In 1959, crude oil production within the base study area in Texas was about 620 million barrels and in Oklahoma 90 million barrels which constituted about 28 percent of the national output.

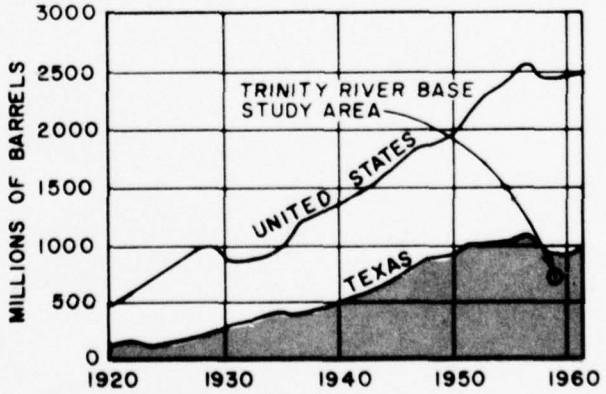


FIGURE 14
CRUDE OIL PRODUCTION

56. The future of oil production in the region is, of course dependent on the recoverable reserves. Most of the available data on petroleum futures is based on the ratio of proven reserves to production and tends to present a conservative outlook on the estimates of ultimate production from United States reserves, both known and prospective. Although a reserve-production ratio decline has actually occurred over the past six-year period, it should be noted that there has been some increase in total national reserves, with Texas reserves remaining about steady through 1960. In late 1960, a new major discovery was made on the James Reef in the Fairway Field which is located within the basin in Henderson and Anderson Counties, Texas. Although the limits of the Fairway Field have not been fully established, it was evident, by the end of 1961, that the field is a major producing field, with a potential recovery presently estimated to exceed one-half billion barrels. New discoveries such as this, together with advanced technology in oil discovery and production permit an optimistic forecast for the possibility of future oil production. The relationship of crude oil production and reserves in Texas as a percent of the United States is shown on figure 15.

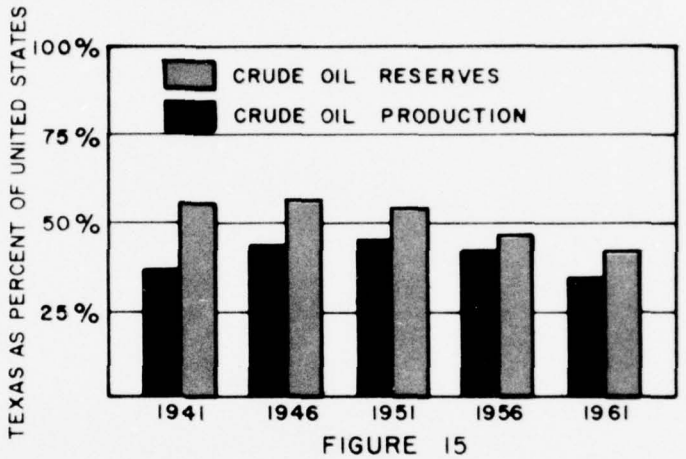


FIGURE 15

PETROLEUM PRODUCTION AND RESERVES

57. Natural gas is considered as the world's best domestic and industrial fuel, and in recent years it has been increasingly used as a raw material for a wide variety of products of the modern chemical industries. Although natural gas resources are widely distributed throughout the southwest region, gas in commercial quantities

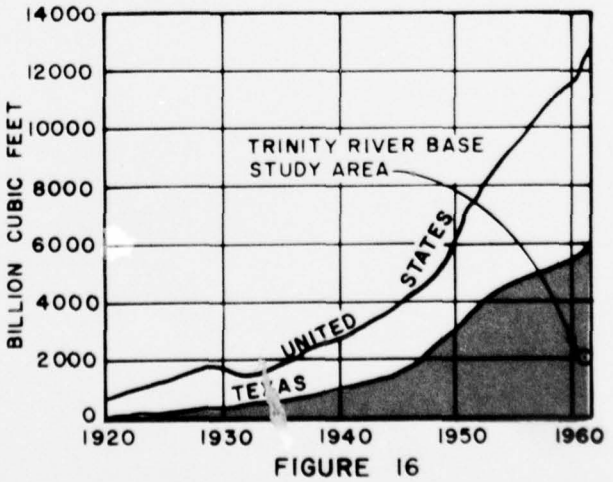


FIGURE 16

NATURAL GAS PRODUCTION

is not as widely found as crude oil. Natural gas production in the State of Texas and the United States from 1920-1961 are shown on figure 16. In 1961, natural gas production within the base study area was about two trillion cubic feet and constituted 16 percent of the production for the United States.

58. In addition to supplying natural gas to more than half of the United States, the State of Texas has nearly one-half of the nation's proven reserves of this mineral. The American Gas Association Committee on Natural Gas Reserves reported that estimated proven recoverable reserves of natural gas in the United States totaled 262.2 trillion cubic feet at the end of 1959, increasing 8.5 trillion cubic feet during the year. The larger gains were reported in Texas and Louisiana, where increases of 4.3 and 3.8 trillion cubic feet, respectively, are shown.

59. Natural gas liquids are also produced in large quantities in the base study area. Liquid gas products, whether obtained from natural gas or processing in refineries, are defined by the Bureau of Mines as natural and finished gasolines, ethane, propane, butane, isobutane, etc. The base study area's production was over 100 million barrels of natural gas liquids in 1959 and is second only to crude oil production in total monetary value of minerals. The American Gas Association Reserves Committee estimated recoverable reserves of natural gas liquids in the United States at the end of 1959 of 6,522 million barrels which was an increase of 362 million barrels or 6 percent over the previous year. The State of Texas, including the offshore area in the Gulf, accounted for 53 percent of the total estimated reserves.

60. Other minerals available in commercially significant quantities from the region are sand and gravel, stone, lignite, common salt, clay, iron ore, and sulphur. The reserves of sand, gravel, and stone (mostly limestone) in the basin are virtually unlimited. Some of the beds of limestone are known to be several hundred feet thick. In the base study area during 1958, 660,000 tons of limestone were used in the manufacture of lime. There are an estimated 20 billion tons of recoverable lignite in the base study area, a large part of which is located within, or adjacent to, the basin. The principal use of this fuel at present is for a 240,000 KW steam-electric plant which furnishes power to an aluminum reduction plant located just west of the basin in Milam County, about 100 miles northwest of Houston. Utilization studies indicate that not only will lignite be used for future power production but also in the chemical, wood preservation, and refining industries. An estimated 72 billion tons of salt are located in salt domes in 9 counties within the base study area. Most of these counties are located within the middle portion of the basin, the average distance from the salt domes to the Trinity River being 33 miles. Iron ore is located mainly in the middle section of the basin and adjacent base study area to the east. Iron ore production in Texas since 1955 has not been disclosed by the Bureau

of Mines. In 1955 about 875,000 long tons were produced, all from strip mines in the base study area. Total recoverable reserves of iron ore, based on the best available information, is estimated at about 175 million tons containing 40 to 50 percent iron. Sulphur is produced in large quantities from four deposits in the base study area, one of which, the Moss Bluff Dome, is located on the Trinity River in Liberty County. Sulphur production in Texas during 1959 was over one-half of the national total.

61. Water.- In relation to future needs, water is the most important natural resource of the area. The residents of the southwest region made a rather late start toward conserving their water resources. Like most frontier people, they took an adequate water supply for granted and, only with the rapid growth of urban population in the last 20 years, has there been a realization that an adequate future water supply was one of the area's big problems. A critical drought, which occurred in this area during the period 1950-1957, caused restriction on uses of water in about one-half the incorporated cities and towns in Texas and demonstrated the seriousness of the water problem. The Trinity River Basin has less length and drainage area than several other Texas river basins, but due to the moderate to heavy rainfall occurring over its drainage area, the flow near its mouth is exceeded only by the Sabine and Neches Rivers. In addition to surface waters, a large portion of the basin is underlain by great natural underground water reservoirs. These ground water supplies have played a tremendous part in the economic development of the area, furnishing water for municipal and industrial needs and irrigation. The five major sources of underground water are the aquifers of the Trinity, Paluxy, and Woodbine sands; the Carrizo Sand and Wilcox group; the Gulf Coast aquifer; the Ogallala Formation; and the Alluvial deposits.

62. The development of water as a natural resource will continue to be a major requirement in providing for the rapid growth and industrial activity of the area. About two million residents of the Trinity River Basin are currently withdrawing approximately 300 million gallons a day from ground and surface water sources to satisfy their needs. As the population continues to expand along with higher living standards during the next century, ever greater demands will be placed on the water resources of the basin.

63. Maintenance of water quality and reduction of stream pollution are essential elements in the future use of water as a natural resource. With the future large expansion of population and industrial activity and the resultant increased waste loads, more attention must be directed to the maintenance of acceptable water quality, either through direct reduction of waste loads or by dilution

from increased stream flow. Failure to recognize and cope with the water quality problems could well result in a barrier to full development of the economic potential of large sections of the basin.

64. Fish and wildlife.- The fish and wildlife resources of the basin proper are important primarily as a basis for hunting, fishing and other outdoor recreation. The commercial fish harvest from the Trinity River is not large. However, flow from the river into Trinity Bay tends to maintain a proper salinity balance with ocean water and create a favorable habitat for various species of commercially important marine life found in the coastal bays and offshore waters of the Gulf. Of the marine products taken by commercial fisheries, shrimp has the largest monetary value but menhaden, a fish used for meal and oil, is the greatest in volume, with about 100 million pounds harvested in 1959. Although fish and wildlife resources, in some of their original locations and native habitat, have declined considerably since the early pioneers settled in Texas, various changes during recent years have contributed to increase the game and fish life. The raising of stock and growing feed crops on the larger, more productive farms, and the practice of allowing large acreages of marginal lands to revert to native vegetation have contributed to providing a much better wildlife habitat. Also the many reservoirs built in the Trinity River Basin during the past 30 years have provided not only increased fishing opportunity but also new habitat for both fish and migratory birds. Future economic and social factors in the area will impose an increasing demand on the fish and wildlife resources and require expanded measures for their conservation and propagation.

65. Recreation.- Because of a favorable climate for outdoor activity during much of the year and due to the tremendous economic growth, the use of water and land resources is becoming increasingly important for development of outdoor recreation opportunities. Provisions for outdoor recreation in the region vary from local facilities such as municipal playgrounds and parks, museums, and stadiums to resource-based recreation areas, selected for their superior natural features, such as National and State Parks and Monuments. However, in this report, the emphasis is placed on water-oriented recreation areas because it is inherent in river basin planning and development.

66. The development of water and related land resources for recreation not only fulfills a need for the social well being of the people but it also contributes to the future economic growth in the local areas where this development takes place. There is substantial demand for water-based recreation facilities, particularly in the upper Trinity Basin near the Dallas-Fort Worth complex. It is anticipated that the expansion in recreational facilities and opportunities for commerce as a result of the development of water resources, together with favorable labor and raw materials supplies, will attract industry and investment in many forms to the area.

Recreation associated with major water resources projects attracts outside investment in a number of ways. Particularly significant are the following:

a. Recreation attracts visitors who in the aggregate spend large sums at lakeshore resorts and service establishments.

b. Recreational visitation induces private investors to put money into overnight accommodations, marinas, and other recreation-related sales and service facilities.

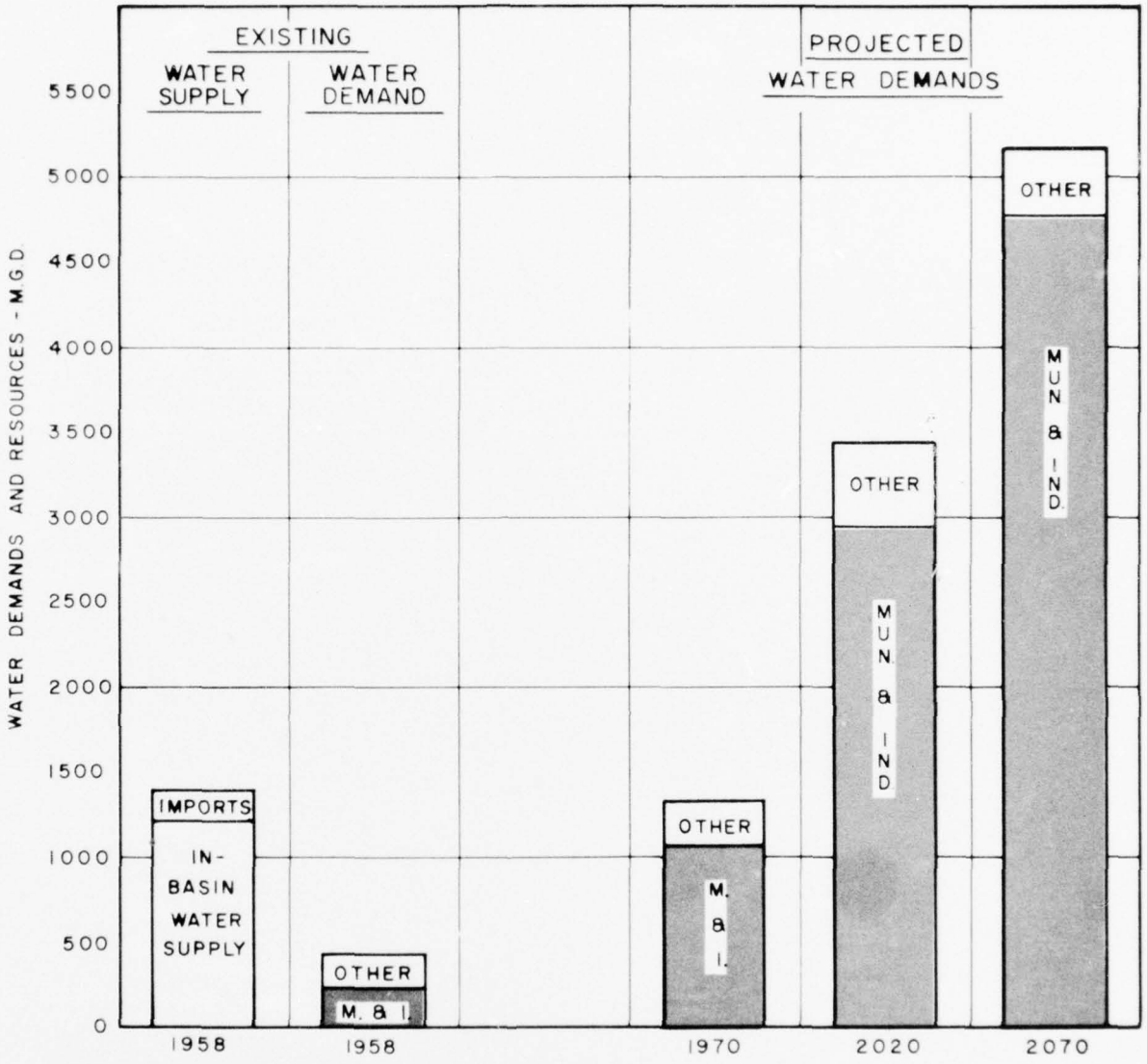
c. Recreational aspects of projects attract newcomers to the reservoir area who construct homes and cabins for themselves on or near the shore lines.

d. Industry is attracted to an area because of the favorable recreational opportunities afforded its employees, even though the industry itself may not be a heavy water user.

RELATION OF THE ECONOMIC DEVELOPMENT TO THE WATER AND RELATED LAND RESOURCES OF THE BASIN

67. INTRODUCTION.- The ultimate aim of river basins programs, in common with all other productive activity, is to satisfy human needs and improve the economic and social well-being of all the people. A basic principle in this investigation is that the water and related land resources development have value only to the extent that they will be needed. The previous section has shown that a portion of the Trinity River Basin is rapidly developing into one of the major urban-industrial areas of the United States. Other areas of the basin and adjacent study area, although potentially favorable for development, have been retarded because of various factors, some of which are water associated. The magnitude of the demands for water resources development and control in the Trinity River Basin is based on the past and present uses as related to the economic activities of the study area and the broad projections of future economic growth. The development and control of the water and related land resources that would contribute to the area's growth and anticipated economy were planned to assure a balanced program of resource development. In the over-all evaluation of the demands on water resources, consideration was given to all available information on present and projected needs as developed by the State of Texas and other Federal agencies, the wishes of local interests as expressed at public hearings, and the directives from Congress for this investigation.

68. DOMESTIC, MUNICIPAL, AND INDUSTRIAL WATER SUPPLY.- The projected widespread increase in population and industrial expansion must of necessity be closely supported by a water supply that is not only sufficient in quantity, but suitable in quality and at a reasonable cost. In the Trinity Basin, the principal problems in meeting these requirements are supplies, distribution, water quality, and variability of flow, all of which will become more acute as the population and economy grow. Water supply in the basin can be a problem if water resources are not developed sufficiently in advance to satisfy projected needs and becomes an acute situation when the demands exceed the available resources. In the Trinity River Basin, as shown on figure 17, about 235 million gallons of water per day were used in 1958 for municipal and industrial purposes. It is anticipated that this requirement will multiply many times in the future. For instance, by year 2020 the requirements will be more than 12 times the 1958 use and by year 2070 the need will have increased to more than 20 times the 1958 use. It is estimated that existing and under-construction water resource developments for municipal and industrial purposes, including present ground water usage and importations and assuming the Soil Conservation Service program in operation, will produce about 1.4 billion gallons of water per day. These supplies are more than



NOTE:
REQUIREMENTS FOR IRRIGATION, NAVIGATION AND WATER QUALITY CONTROL INCLUDED AS "OTHER."

FIGURE 17

TRINITY RIVER BASIN

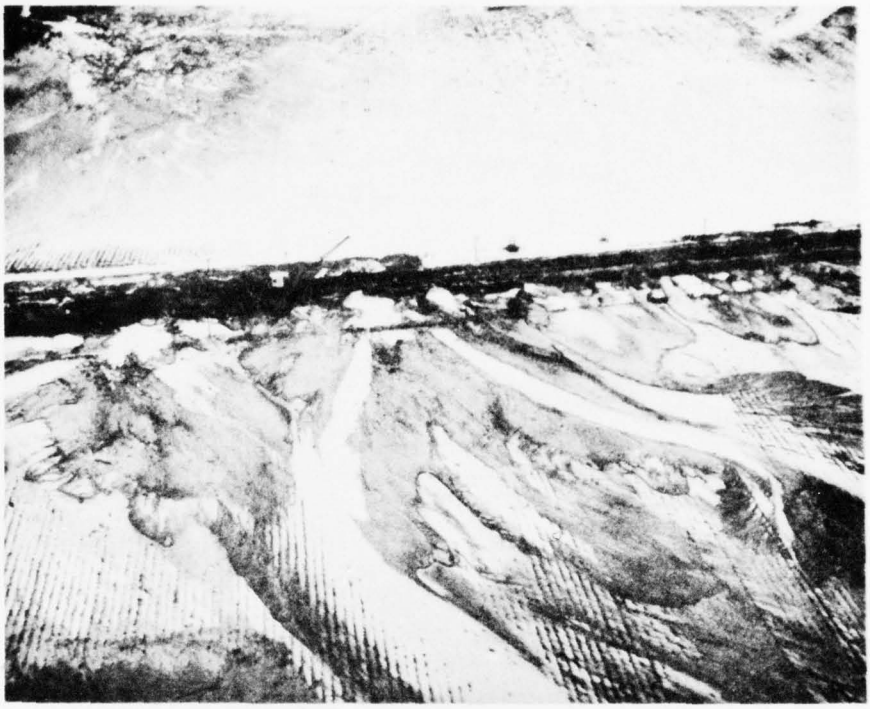
EXISTING AND PROJECTED WATER DEMANDS

adequate to satisfy the projected municipal and industrial demands in the upper and lower basin until about the year 1970. As the need arises in certain areas to satisfy the increasing population and industrial expansion, additional successive increments of water resources can be developed. These developments may include additional reservoir projects in the basin, more efficient use of return flow, increased ground water use, and additional importations.

69. FLOOD CONTROL.- The Trinity River Basin, like many others in the State of Texas and throughout the country, experiences at various intervals the natural phenomena of floods -- too much water. This problem dates back to the earliest settlements located on the level flood plains along the main stem and principal tributaries. Many of the early settlers built small levees to protect their property but invariably the levees were overtopped. Later, local organized groups in the form of levee districts, and finally the Federal Government took an interest in the flood problem and their efforts have grown until flood control has become one of the major public works activities. The battle between man and streams for possession of flood plain lands has been long and costly. There are many influencing factors which contribute to the complexity of the problem, such as: the unrelenting efforts of man to wrest valley lands from the streams to which, under the laws of nature, they belong; the attractiveness of the flood plain which causes man to overlook or ignore the threat of flood damage and use this area for homes, industry, and agriculture, the lesser cost of building on relatively flat valley bottoms and partial protection from flooding which encourages greater use and development of the flood plain. Flood scenes in the Trinity River Basin are shown on figures 18 and 19.

70. There are many areas throughout the Trinity River Basin with an abundance of natural resources and development opportunities, such as the middle section, which have only limited development primarily because these areas are subject to frequent flooding. These areas will prosper only when the flood problems have been eliminated. An outstanding example of what may be achieved by elimination of a flood threat and through planning foresight and personal initiative can best be demonstrated by what has taken place at Dallas, where an agricultural area in a relatively few years has been converted into a tremendous industrial development.

71. In the Trinity River Basin there are about 1,550,000 acres of land subject to being flooded, of which over 830,000 acres are situated along the main stem and lower reaches of the principal tributaries and the remaining 720,000 acres are in the headwater tributary streams. The 720,000 acres subject to flooding on the headwater tributaries will be considered for protection under the runoff and waterflow retardation and soil erosion prevention programs of the Soil Conservation Service. Of the 830,000 acres subject to flooding on the main stem and principal tributaries, about 225,000 acres are, or will be, afforded a high



FLOOD OF APRIL-JUNE 1957 ON
RICHLAND CREEK NEAR CORSICANA, TEXAS

1949 FLOOD ON THE CLEAR FORK AT FORT WORTH

FIGURE 18

WEST FORK TRINITY RIVER – MAY 1949

BIG FOSSIL CREEK—APRIL-JUNE 1957

FIGURE 19. URBAN FLOOD SCENES
VICINITY OF FORT WORTH, TEXAS

degree of flood protection by existing, authorized, and previously recommended Corps of Engineers projects. Flood protection to the remaining 605,000 acres of flood plain is considered in this report. This flood plain consists of 586,400 acres of agricultural land and 18,600 acres of urban and suburban development. The annual value of crops produced in the flood plain under present conditions amounts to about $17,250,000. The total value of physical property in this flood plain is about 327 million dollars under present conditions of basin development. With the projected widespread increase in population, industrial expansion, and service facilities, this value is expected to increase without additional flood control works, to about 1, 3.5, and 5.4 billion dollars in 1970, 2020, and 2070, respectively, as shown on figure 20.

72. In the basin a number of multiple-purpose reservoir and local flood protection projects, as shown on figure 1, have been constructed over a period of years in an attempt to alleviate the flood problem on the main stem and principal tributaries. Many of these improvements such as the reservoir projects on the West Fork of the Trinity River and numerous levee projects in the upper basin have been developed by local interests for flood protection. The value of such flood protective works was demonstrated by the 1957 flood, during which Corps of Engineers projects alone prevented damages estimated at about 85 million dollars. The April-June 1957 flood, which caused flooding throughout the entire Trinity River Basin, resulted from a series of storms which occurred over a period of about three months. This flood was one of the most damaging in the history of the basin and caused damages estimated at $19,500,000. Economic studies indicate a tremendous population and industrial expansion in the Trinity River Basin during the next century. Based on this projected growth, a recurrence of the April-June 1957 flood, with existing and authorized protection, would cause damages estimated as follows:

Date	Estimated Damage (Dollars)
1960	15,200,000
2020	163,600,000
2070	251,100,000

73. The average annual damages on the Trinity River and principal tributaries under 1960 conditions of flood plain protection and development are estimated to be about $3,000,000. The average annual damages on the 605,000 acres of flood plain studied in this report under 1960 conditions of economic development based on existing, authorized, and previously recommended flood-control projects are estimated to be about $2,300,000 as shown on figure 21.

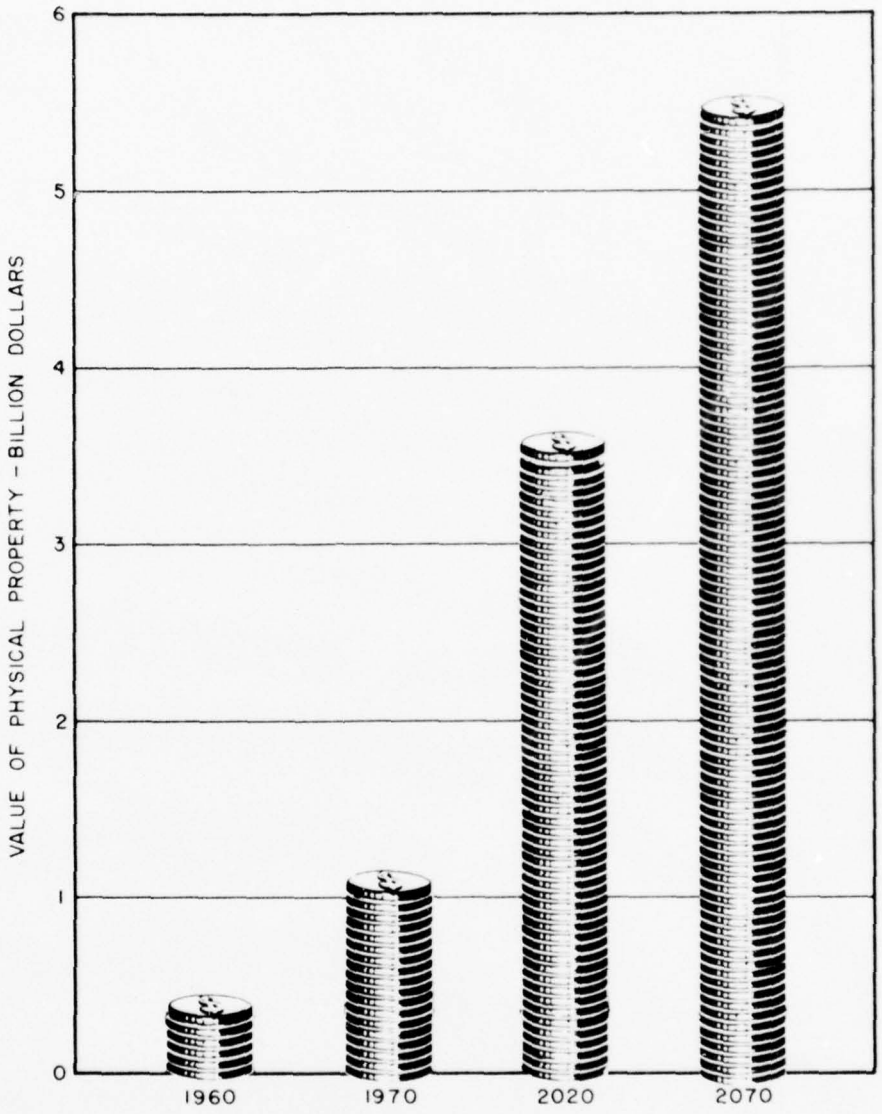


FIGURE 20

VALUE OF PHYSICAL PROPERTY IN FLOOD PLAIN
UNDER 1960 FLOOD-CONTROL PROJECT DEVELOPMENT
MAIN STEM & PRINCIPAL TRIBUTARIES

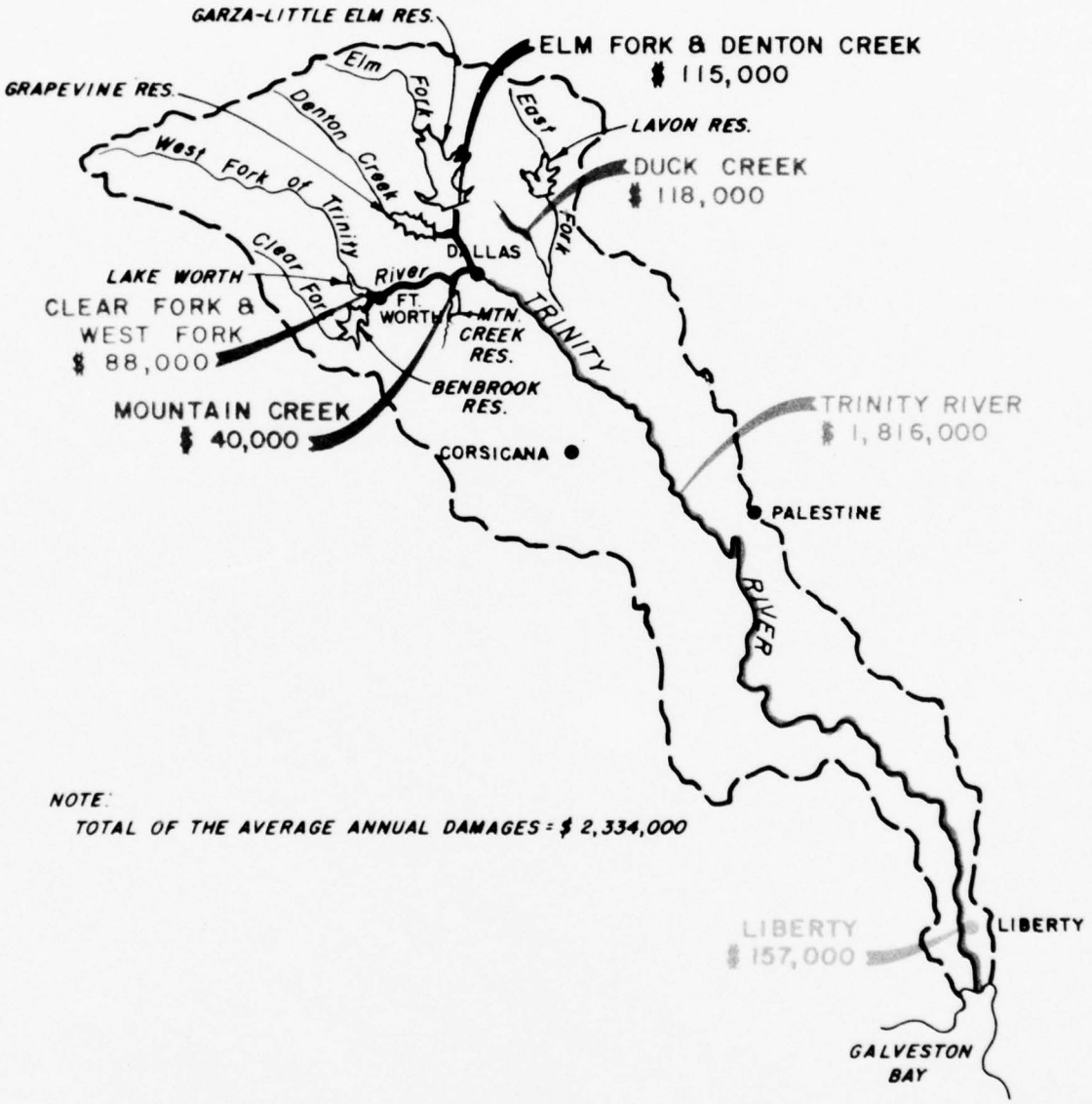


FIGURE 21

AVERAGE ANNUAL FLOOD DAMAGES

UNDER 1960 FLOOD-CONTROL PROJECT AND ECONOMIC DEVELOPMENT

MAIN STEM AND PRINCIPAL TRIBUTARIES

74. The present and future flood problems of the basin may be most effectively prevented by protective measures, such as reservoirs, local flood protection projects, channel improvement works, levee systems with appurtenant interior drainage facilities, and land treatment and water retardation programs. The flood control effectiveness of these works of improvement would be enhanced tremendously through the flood forecasting and improved flood warning systems of the U. S. Weather Bureau and flood plain information studies of the Corps of Engineers.

75. NAVIGATION.- The economic development of an area is greatly stimulated by a complete transportation complex that includes all forms of transportation including navigation. The need for a navigable waterway is dependent upon sufficient volume of those commodities that can be moved at a savings by this form of transportation. The prime requisite for efficiency in barge transportation is consolidation of large volumes of freight at one point. Waterway service is generally restricted to a fairly limited range of commodities which are mostly bulky and, in many instances unprocessed items, which constitute well over half of the total goods moving in the United States. Bulk grains, metal ores and manufactured products, thermal energy fuels and unprocessed non-metallic minerals are typical commodities particularly adaptable to low-cost waterway transportation. Waterway transportation offers the only feasible method of transporting some of the enormous and complex mechanisms that are being assembled and must be transported long distances in the country's rapidly expanding scientific development. The location, resources and trends of economic development of the Trinity River Basin are favorable to the generation of large volumes of commerce in these commodities. The nation's principal grain belt lies to the north and northwest of the basin. A continuous flow of export grain moves southward by rail and truck to deepwater ports on the Gulf Coast. The industrial complexes of the Dallas-Fort Worth and Houston areas generate large movements in both directions of raw and semi-processed materials, manufactured products, bulk chemicals, petroleum and petroleum products. Water transportation would make the extensive deposits of lignite and coal in the basin available to supply the demands of Texas and the Nation for energy as fossil fuels become more competitive with petroleum, natural gas and other forms of energy. There are large deposits of stone, sand and gravel in the basin that, with low-cost barge transportation, would be extensively developed and worked for outside markets. In view of the superiority of water transportation for some elements of the mass transportation market, an objective evaluation was made of the need, prospective use and economic feasibility of the waterway.

76. Potential use of waterway.- To evaluate the potential commerce for a navigable Trinity River Waterway, a field canvass and traffic survey was made of a 178-county area in Texas and Oklahoma. The traffic area was delineated after study and analysis of the existing tariff rates and points of origin and destination for movement of selected commodities, known to be adaptable to barge movement and susceptible to routing, either wholly or in part, on the proposed Trinity River Waterway. The field canvass, completed late in 1958, was made by traffic and transportation

specialists and included personal interviews and correspondence with about 2,000 potential shippers and receivers throughout the traffic area. The survey also included a canvass of major shippers presently using the extensive inland waterway system, with which the proposed Trinity River Waterway would connect at the Houston Ship Channel. The principal coastal and inland waterways of the eastern United States are shown on figure 22. The growth of commerce on Texas waterways between 1950 and 1959 is shown on figure 23. It is pertinent to note that the growth experienced by the Gulf Intracoastal Waterway traffic increased by over 50 percent in the decade from 1950 through 1959. Similar increases were evidenced in the barge traffic of the major deepwater ports of Texas.

77. The traffic survey developed a total of 114 separate commodities in 10 major classifications that were adaptable to waterborne commerce and moving in the traffic area in sufficient amounts to warrant consideration as potential commerce. The potential in 1958 for barge movement of these commodities if a navigable waterway existed from the Houston Ship Channel to Fort Worth was estimated at 45 million tons annually.

78. Prospective commerce.- The 1958 potential of 45 million tons was subjected to a rigorous screening out of those commodities that would not move on the waterway. Certain potential commerce was eliminated for one or more reasons, including the following: apparent duplication of tonnages reported by shippers and receivers; excessive circuity of routing; not adaptable to barge transportation because of special handling requirements, insufficient total volume shipped or necessity for small, frequent shipments; more probable movement on other waterways and little or no savings by water transportation because of existing tariff rate consideration or comparatively large transfer and handling costs. The residual potential commerce then was subjected to a rate analysis process. Special studies of the prospective movement of sand, gravel, stone and grain were made. Of the 45 million tons of potential 1958 commerce, 38,078,000 tons were eliminated to leave a total of 6,922,000 tons of prospective commerce that would move by barge if an improved channel existed along the river. The commerce considered to be presently prospective comprises 42 commodities in 9 major classification groupings and is shown by direction of movement in table 5.

79. Of the 42 commodities included in the nine classes of accepted prospective commerce, the principal ones are 2,210,000 tons of downbound grain (item 2); 2,934,000 of sand, gravel and stone moving in both directions (included in item 6); 709,000 tons of upbound iron and steel articles, and 314,000 tons of downbound iron and steel scrap (included in item 7). These commodities comprise about 89 percent of the total prospective commerce. About 19 percent of the total upbound commerce would originate on the Ohio and Upper Mississippi River inland waterways system, 10 percent would originate on the Gulf Coast at and east of New Orleans, with the remainder originating along the Texas coast and the Trinity River. Most of the downbound commerce would terminate along the Gulf Coast west of New Orleans, either for domestic use or for export through the deepwater ports of Houston and Galveston.

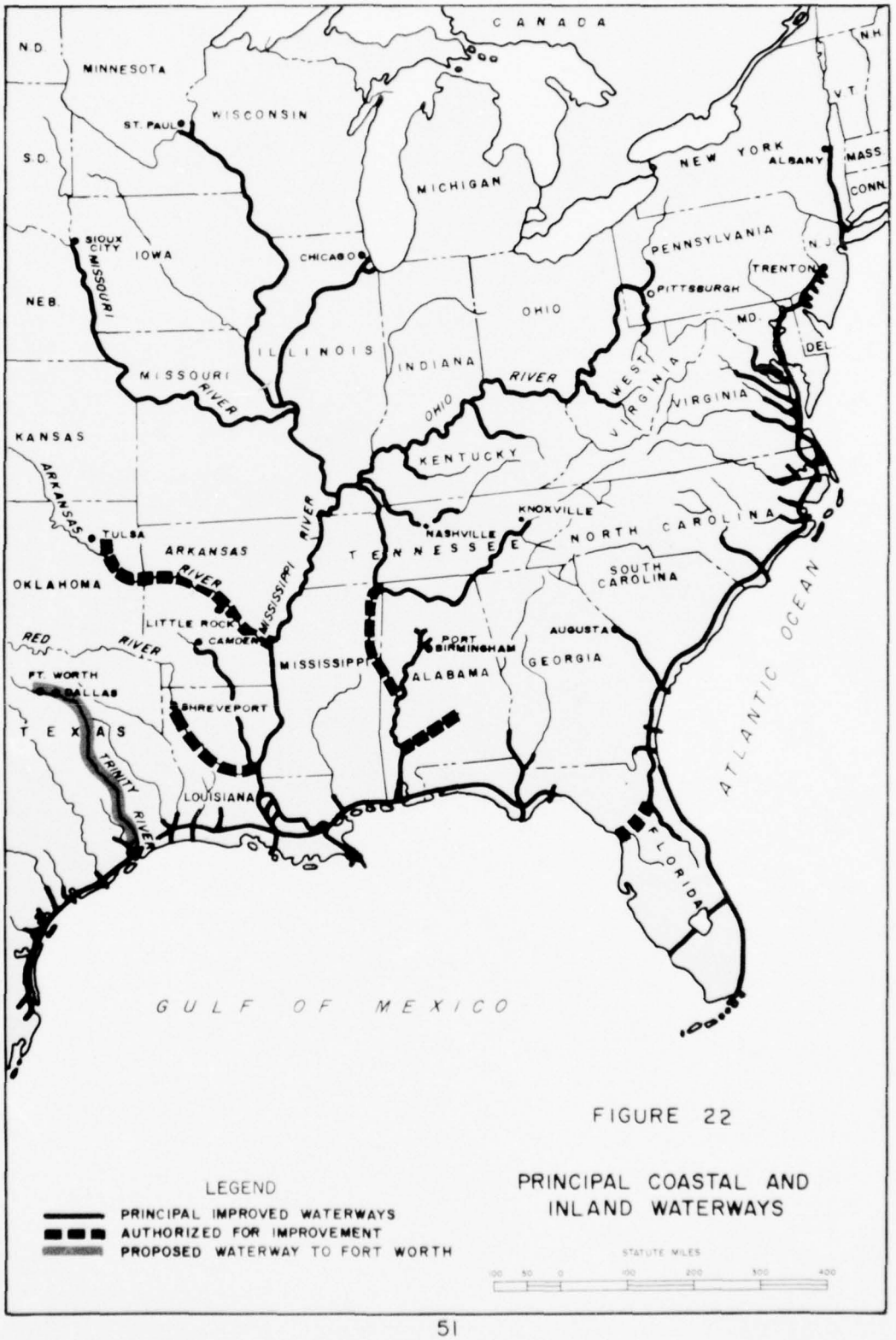


FIGURE 22

PRINCIPAL COASTAL AND INLAND WATERWAYS

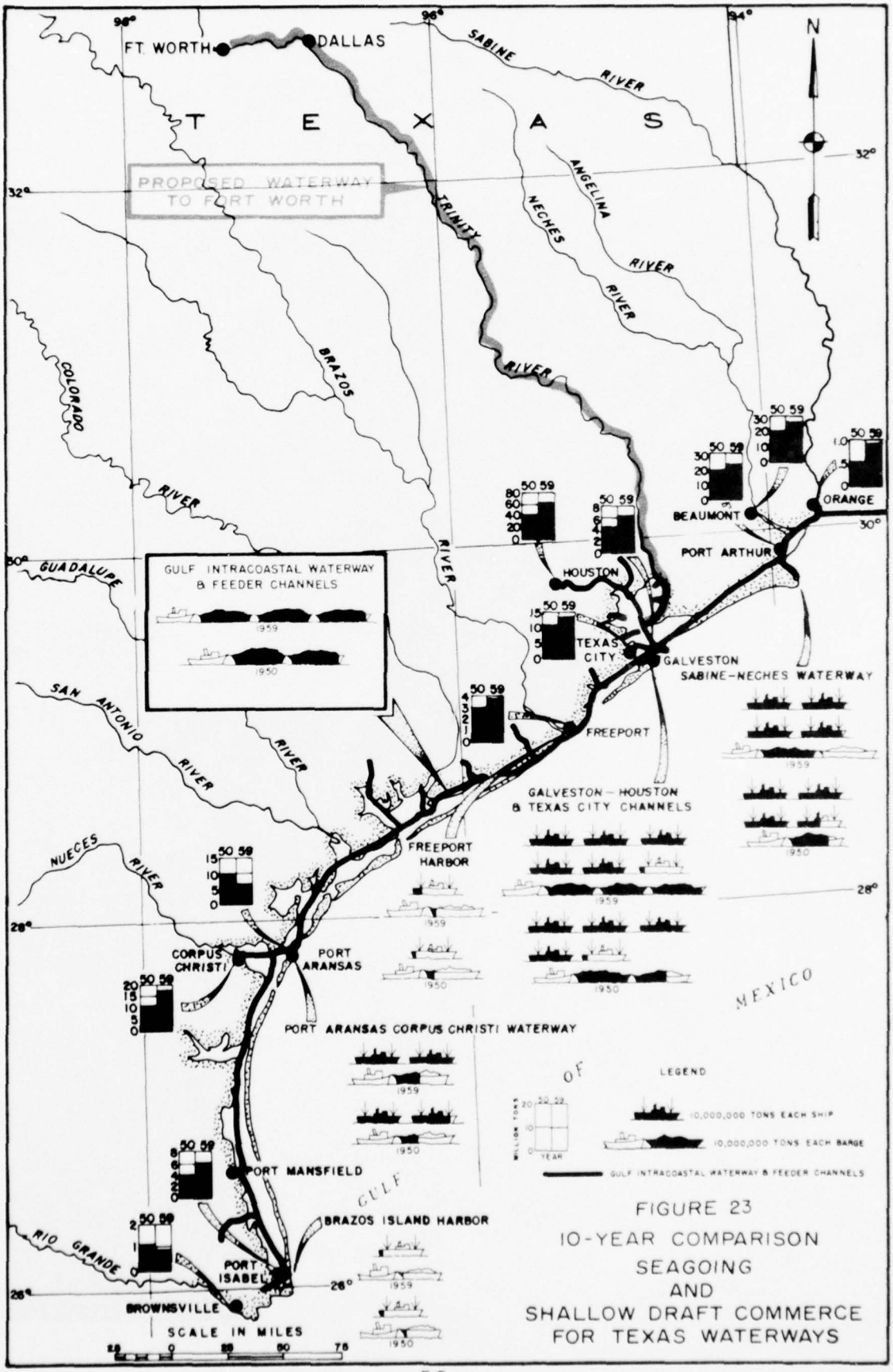


FIGURE 23
10-YEAR COMPARISON
SEAGOING
AND
SHALLOW DRAFT COMMERCE
FOR TEXAS WATERWAYS

TABLE 5

1958 PROSPECTIVE WATERWAY COMMERCE
BY MAJOR CLASSES OF COMMODITIES

Item	Class of Commodity	Annual prospective waterway commerce: Upbound (tons)	Downbound (tons)	Total (tons)
1	Animal & animal products, inedible	62,000	-	62,000
2	Vegetable food products & beverages	-	2,210,000	2,210,000
3	Vegetable products, inedible, except fiber & wools	121,000	-	121,000
4	Textile fibers & manufactures	6,000	2,000	8,000
5	Wood & paper	153,000	-	153,000
6	Non-metallic minerals	1,171,000	1,838,000	3,009,000
7	Metals & manufactures, except machinery & vehicles	712,000	365,000	1,077,000
8	Chemicals & related products	166,000	113,000	279,000
9	Miscellaneous	3,000	-	3,000
	Totals	2,394,000	4,528,000	6,922,000

80. Projected prospective commerce.- The anticipated expanding economy of the basin would increase the prospective commerce on the waterway and in turn would be accelerated by the availability of water transportation. In order to estimate the prospective waterborne commerce over the life of the project, an extensive study was made of the basic economy of the basin and its future development. Basic economic factors closely related to the commodities comprising the waterway traffic were selected and the history and growth of these factors were projected over the life of the project. Indicators were developed from the projections of these growth factors and applied to the related groups of commodities in the 1958 commerce to determine the projected waterway commerce. The total prospective commerce so developed for the proposed waterway to Fort Worth amounts to 8,828,000 tons in 1970, 22,903,000 tons in 2020, and 72,080,000 tons in 2070.

81. The Trinity Improvement Association in 1957 completed a preliminary survey of prospective barge commerce for a modern, canalized waterway extending in the Trinity River from the Houston Ship Channel to Fort Worth. The Association found prospective commerce of 8,270,000 tons upbound and 5,669,000 tons downbound, or a total prospective movement of 13,939,000 tons annually. The prospective commerce developed by the Association comprised 10 general classes of commodities and more than 75 separate commodities.

82. At the public hearing held in Fort Worth, Texas, on

December 20, 1961, when features of the preliminary plan then being considered for inclusion in this report were presented to local interests, representatives of the Texas Railroad Association spoke in opposition to the proposed navigation improvement and gave the Association's estimates of prospective commerce on the proposed waterway. Assuming the waterway had been in existence during the year 1959 and that prospective commerce was fully developed, the Association estimated that the commerce would have totaled 2,587,000 tons. This prospective commerce comprises twelve commodities, ten of which are included in and account for 91 percent of the total prospective commerce developed for this report. The three largest items in each estimate account for about 72 percent of the difference. Of these the Association allowed 66 percent of the sand and gravel, 26 percent of the grain and 22 percent of the iron and steel,except pipe, for a total of 2,446,000 tons compared to 5,586,000 tons. For the 50-year period 1971-2020, the Association estimates an average annual prospective commerce of 5,751,000 tons. Assuming a uniform annual increase from 1959 this estimate would result in about 9,900,000 tons of commerce in 2020 or about 45 percent of the estimate developed in this report.

83. IRRIGATION.- The development of the basin has progressed from an agrarian beginning to the present economy which includes substantial urbanization and industrialization. During the next century, the projected development of the basin will have a marked effect on the agricultural economy of the basin. Irrigation is one of the many resource development opportunities which will be used to increase future food and fiber production. In the Trinity River Basin and adjacent coastal area, about 68,000 acres of land were irrigated in 1958 with a total water use of about 165,000 acre-feet. Present surface-water irrigation is concentrated largely in the lower basin where water is diverted from the Trinity River for rice production. There is some additional surface water irrigation on numerous small tracts scattered along the Trinity River below Dallas and along several tributaries. In addition to the surface-water irrigation there is some ground-water irrigation in the lower portion of the basin and on small, scattered tracts throughout the basin.

84. Based on the projected population and industrial expansion and increased water demands in the Trinity River Basin, it is believed that irrigation in the future will remain about the same except along the Trinity River below Dallas. A study of available land resources revealed that about 42,000 acres between Dallas and the Tennessee Colony Reservoir site; about 49,000 acres between that site and the Livingston Reservoir; and about 80,000 acres in the lower basin and in the adjacent coastal area for a total of 171,000 acres are physically suitable for sustained permanent-type irrigation and production of agricultural crops and have been considered in the overall plan of development for the basin. The projected water requirements for irrigation of these areas are 356 million gallons per day or about 399,100 acre-feet per year.

85. Existing appropriative water rights and permits provide for the future irrigation of 80,000 acres in the lower basin and adjacent coastal area. However, in the interest of developing the remaining 91,000 acres of land along the Trinity River, consideration was given to Federal project-

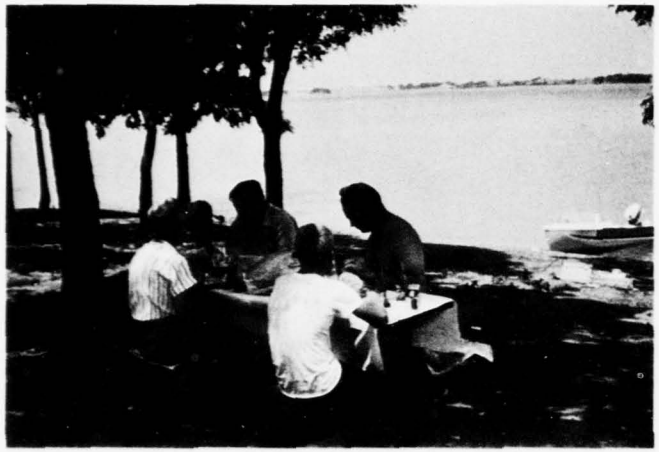
type facilities. From a study of these areas, the Bureau of Reclamation concluded that since the areas lie in scattered tracts along the river, they are best suited for development by individual landowners rather than large project-type irrigation. However, information furnished by the Soil Conservation Service indicates that some irrigable areas are well-adapted to small project-type development under Public Law 566, as amended. The municipal and industrial return flows from the Fort Worth-Dallas area will provide a large sustained flow that will be physically accessible to landowners desiring to irrigate holdings along the main stem. Irrigation by local interests has been recognized as a part of the comprehensive plan and water requirements of 356 million gallons per day were included in the determination of the total water supply needs of the basin.

86. RECREATION.- The demands for outdoor recreation have greatly accelerated in recent years. Much of this recreation activity is concerned with the use and enjoyment of our water resources. Regardless of the measure used -- number of visitors to Federal and State recreation areas, number of fishing license holders, number of outboard motors in use -- it is clear that Americans are seeking the outdoors as never before. Water is a key factor of recreational development and serves as a magnet since both urban and rural areas show a strong urge for water-oriented recreation.

87. The general public through a better standard of living and by education and participation has found that outdoor recreation produces many benefits -- it provides healthful exercise necessary for individual physical fitness; it promotes mental health; it offers spiritual values -- for being in the outdoors can be a deeply moving experience; it is valuable for education in the world of nature; and it satisfies simple recreational needs whether they be a path to walk along, an attractive road for a drive, a place to swim, or a shady spot for a picnic.

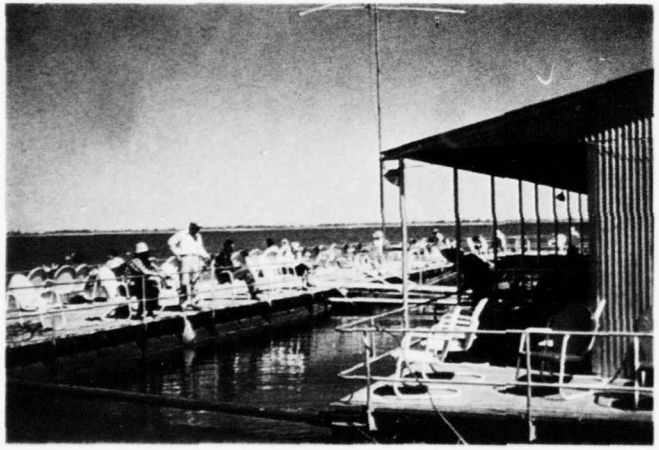
88. The national trend of water-oriented recreational demands and activities is reflected in the Trinity River Basin. In the general area of the Fort Worth-Dallas-complex, a number of major reservoirs have outdoor recreational opportunities available. Visitor statistics are available for the four Corps of Engineers reservoirs, Benbrook, Grapevine, Garza-Little Elm, and Lavon, where the general public has free access to Federally provided outdoor recreation facilities. These reservoirs attracted over eight million visitors in 1961, with almost three million engaging in sport fishing or hunting. Scenes of general recreational activities at Corps of Engineers projects are shown on figure 24.

89. With the rapid increase in population accompanied by more leisure time and money to spend on recreation and better travel facilities, a tremendous increase in the demand for recreational facilities will occur, as shown on figure 25. By year 2020 recreational facilities will be needed to accommodate about 38 million visitors and by year 2070 about 78



PICNICKING - LAVON RESERVOIR

BOAT STORAGE - GRAPEVINE RESERVOIR



FISHING BARGE - GARZA-LITTLE ELM RESERVOIR

BOATING - GARZA-LITTLE ELM RESERVOIR

FIGURE 24
RECREATION AT CORPS OF ENGINEERS PROJECTS

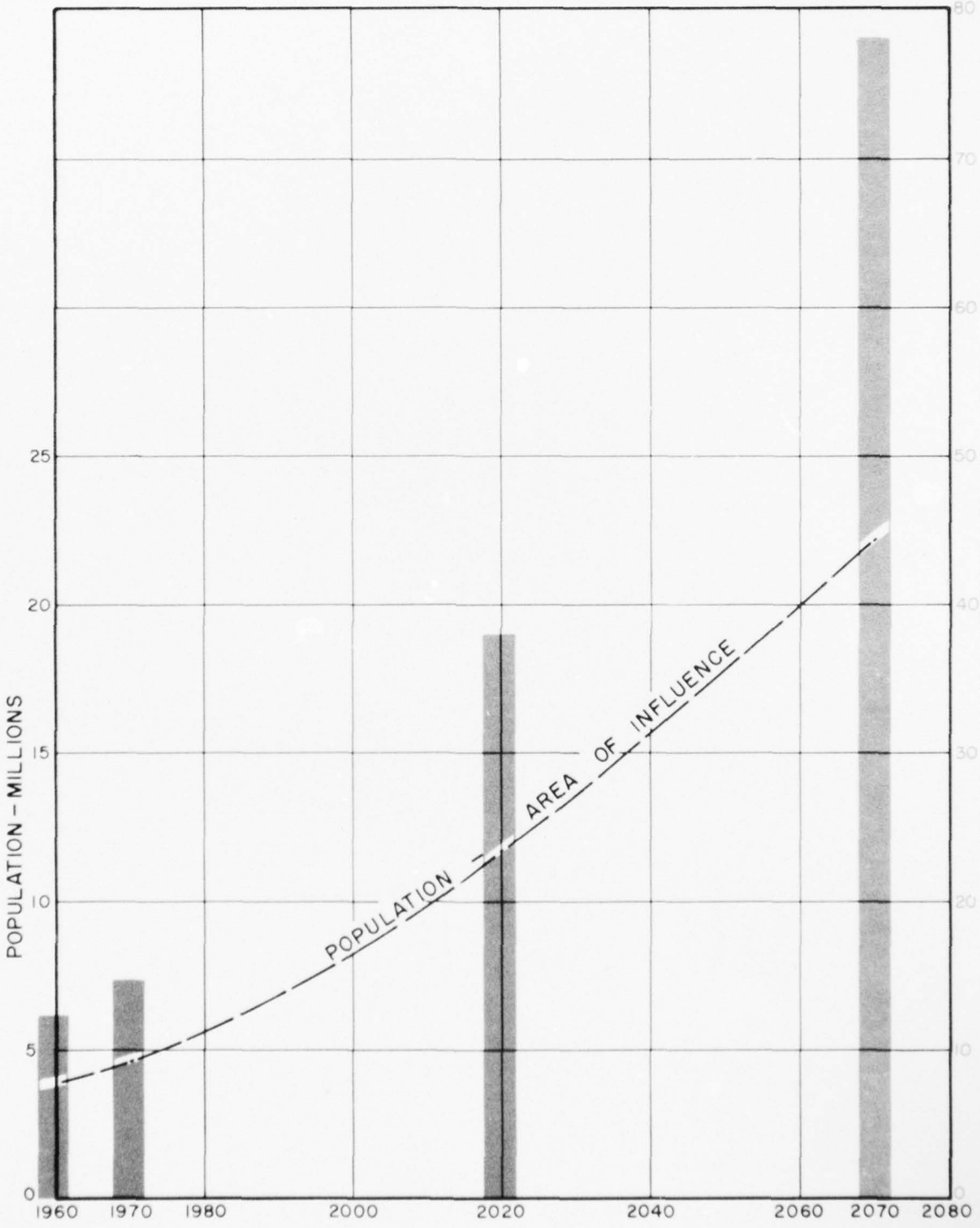


FIGURE 25

WATER BASED
RECREATION DEMANDS

million visitors. Of the total visitors participating in water-oriented activities, about 65 percent will be engaged in general recreation and about 35 percent in fish and wildlife recreation. The comprehensive plan will include development of the natural resources of each project in the interest of satisfying the projected recreational needs.

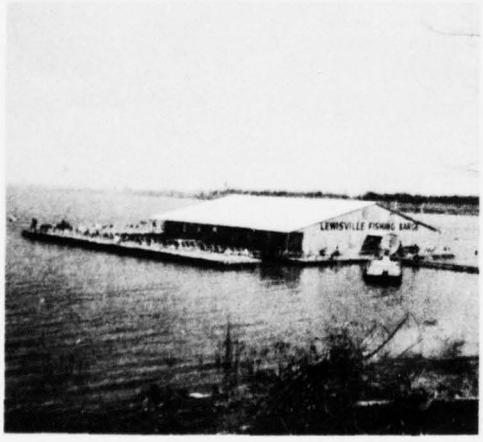
90. FISH AND WILDLIFE.- Fish and wildlife are living natural resources of the Trinity River Basin and, like other living things, they are initially associated with the land and water. A great deal is at stake in the preservation and development of our fish and wildlife resources since they are vitally important to our economy and way of living. The recreational value of fish and wildlife is of profound significance to the well-being of people, possibly even more so than the food value of this resource. In our way of life, we no longer have to hunt and fish for food, but the pleasure and sport of hunting and fishing are widely enjoyed. In an age of hustle and bustle, where the effects - both physical and emotional - from the stress of modern-day living are reflected in our daily lives, it has been stated that "fishing and hunting in the outdoors are better antidotes for modern-day stresses than the use of tranquilizer pills." The opportunity to hunt and fish will not automatically remain, and fish and wildlife resources must be considered in the overall planning for the basin. Fishing scenes on Corps of Engineers projects in the Trinity River and adjacent basins are shown on figures 26 and 27.

91. In the State of Texas and especially in the Trinity River Basin, based on statistical data compiled by the Corps of Engineers, indications are that the percentage of Texans who hunt and fish is about 10 percent higher than the national average. In the Fort Worth-Dallas complex, fishing and hunting privileges are generally available to the public on the four major reservoirs constructed by the Corps of Engineers. It has been determined that about 35 percent of the visitors to these reservoirs was either fishermen or hunters. Based on this percentage, the potential fisherman-hunter visitor attendance to projects within the basin will be about 13 million by year 2020 and about 27 million by year 2070. The projected demands for hunting and fishing opportunities generated by the growing population have been considered as an important element in the comprehensive basin plan since it is considered desirable to satisfy these requirements to the maximum extent practicable.

92. WATER QUALITY CONTROL.- The quality of water is of critical concern in planning for the use of this resource, since toxic or obnoxious pollutants may render the water unfit for human consumption and chemical or mineral pollutants may render it unsuitable for industrial and agricultural purposes. The natural pollutants of dissolved chemicals and suspended sediments are augmented by municipal sewage and industrial effluents. Water pollutants may be classified according to eight general categories: (1) sewage and other oxygen demanding wastes, (2) infectious

BENBROOK

LAVON



GARZA – LITTLE ELM

GRAPEVINE

FIGURE 26

FISHING AT CORPS OF ENGINEERS PROJECTS
TRINITY RIVER BASIN

DAM B

WHITNEY

DAM B

DAM B

FIGURE 27

FISHING AT CORPS OF ENGINEERS PROJECTS

agents, (3) plant nutrients, (4) organic chemical exotics, (5) other mineral and chemical substances, (6) sediments, (7) radioactive substances, and (8) heat. Although each of the above may not be an influencing factor at the present time, it is recognized that they can cause problems of great concern and will increase manyfold in the future. Quality analysis by the U. S. Public Health Service is based on broad parameters which are currently available for evaluation of present and future stream conditions. Total dissolved solids projections have been employed to characterize the effects of stable pollutants (those constituents which are not utilized or reduced by stream environment). Dissolved oxygen content is applied as a measure of unstable pollutants (those constituents which decay and act on, or are acted on, by the stream environment). Mineral content and suspended sediment are measured in parts per million of the pollutant in the water supply.

93. There is justifiable concern over the widespread and perhaps serious increase in the water quality problems resulting from the large increase of population in the Trinity River Basin. The basin population was about two million in 1960, with a projected increase to about six million by 2020 and over eleven million by 2070. A large portion of the increase will occur in the upper section of the basin.

94. The mineral quality of the Trinity River Basin can be presently described as good to very good except for the extreme lower portion of the basin in the coastal region where intrusion of salt water from the Gulf of Mexico has frequently increased dissolved solids concentrations to as much as 1,000 parts per million. The construction of the previously recommended Wallisville Reservoir will eliminate the salt water intrusion problem on the lower basin since it will act as a barrier. As development proceeds, however, waste loads will increase; demand on water will become more prevalent; and increased concentrations of mineral solids can be expected throughout the basin.

95. Above Fort Worth and below Livingston Reservoir, the organic quality of the water can be classified as good. Below the confluence of Marine Creek with the West Fork in Fort Worth and downstream to Rosser in Kaufman County, conditions in the river are generally anaerobic and associated offensive odors persist. Downstream from Rosser, sufficient tributary dilution and reaeration occur, almost overcoming the effect of the organic pollution upon reaching Livingston Reservoir. Since the 100-mile reach of the river from the vicinity of Fort Worth to below Rosser is septic at the present time and this condition will continue in view of the projected growth and development of the area, remedial measures for water quality control are urgently needed in the interest and well-being of the people.

96. SOIL CONSERVATION SERVICE PROGRAM.- The Soil Conservation Service is fully cognizant of the effect of land and water resources

on the present and future agricultural economy of the basin and is actively engaged under authority of the Flood Control Act of 1944 (PL 534, 78th Congress, 2d Session) in the development of work plans and the implementation of a Watershed Improvement Program for the reduction of flood damages and the preservation of agricultural resources. The program generally consists of two major phases of construction - the land treatment measures and the structural measures for flood prevention, sediment control, and water management.

97. An evaluation of the economic trends indicates that there is a general increase in urban expansion underway and a shift in total employment from agricultural to non-agricultural. With the population projections and urban expansions, more land would be shifted to non-farm uses which would result in less total land remaining for agriculture. It therefore becomes a significant factor that the present land and water resources must be developed for maximum utilization.

98. The Corps of Engineers and the Soil Conservation Service have for a number of years been actively engaged in developing plans and projects which are complementary in the interest of a fully developed comprehensive plan. Although considered on a comprehensive watershed basis, the Soil Conservation Service has generally concentrated its activities on the headwater tributaries, whereas, the Corps of Engineers has confined its activities to the main stem and principal tributaries. The coordinated activities of these agencies will continue to contribute to the sound economic growth and well being of the basin.

99. The Soil Conservation Service estimates the total average annual floodwater, sediment, flood plain erosion, and indirect damages in the headwater tributary areas, under present conditions of flood plain development, to be about $7,300,000. In the interest of the preservation and maximum utilization of the natural resources of the basin and to sustain the agricultural economy, the Service, in cooperation with 27 Soil Conservation Districts in the basin, has underway an effective land treatment program based on the use of agricultural land within its capabilities and its treatment in accordance with its needs. The Soil Conservation Service has prepared a number of work plans on selected subwatersheds of the Trinity River Basin in accordance with the desires of, and in cooperation with, local interests based on the needs of the basin. As a result of these work plans the Soil Conservation Service

as of January 1961 had completed about 40 miles of channel improvements and the construction of 288 floodwater retarding structures. These structures have a total storage capacity of 252,500 acre-feet, with 41,100 acre-feet for sediment storage and 211,400 acre-feet of flood detention storage.

100. The U. S. Study Commission - Texas with the realization of the tremendous projected growth in population and industrial expansion and the impact of these developments on the land and water resources and agricultural economy requested the Soil Conservation Service to develop a preliminary plan for upstream flood prevention and water resources development in the Trinity River Basin. This basin plan which includes both existing and proposed improvements indicated that soil conservation measures were justified in 26 subwatersheds comprising 21 percent of the basin and that a total of 1200 floodwater retarding structures with a total capacity of about 1,300,000 acre-feet should be provided at an estimated cost of about 61 million dollars. In addition the plan provides for about 400 miles of channel improvement at an estimated cost of about 14 million dollars or a total structural cost of about 75 million dollars.

101. POWER.- The growth of electric-generating capacity in Texas is the fastest of any state in the nation. The Fort Worth-Dallas area is the second most densely populated and industrialized area in the State of Texas and utilizes a significant percentage of the total power generated in the state. In the Trinity River Basin upstream from Trinidad where the Fort Worth-Dallas area is the hub of activities for steam-electric-generating capacity there are nine major plants with an installed net capability of over 2 million kilowatts. Through the interconnected systems of the Texas Utility Company the net capability of these plants is about 3,700,000 kilowatts. The future power needs of the Trinity River Basin can best be illustrated by what has happened during the past ten years as reported by the Texas Utility Company which services most of the Trinity River Basin. The net generating capability has increased from about one to four million kilowatts; the energy sales have grown from about 4 billion to nearly twelve billion kilowatt hours; the peak load has increased from less than one million to about three million kilowatts; and the investment in plant, property, and equipment has increased from over three hundred million to over nine hundred million dollars. The impact of the population and industrial expansion and ever-increasing demand for additional power is quite evident at the present time since substantial enlargements are presently underway at several of the existing plants.

102. Consideration was given to the development of hydroelectric power, including the use of pumped storage. The low topographic relief of the Trinity Basin is not favorable for either conventional or pump-storage projects. The requirements for use of the water resources

for other higher priority purposes precludes development of water specifically for hydroelectric power generation or its use for power generation in conjunction with other purposes. Studies indicated that, under the most favorable conditions, hydroelectric power generation in small amounts might be economically justified in the future.

103. Power planning for the future.- The future power requirements of the basin are expected to be supplied by the utility companies as the needs develop. This conclusion is based on the progressive developments which have taken place during recent years where the Texas utility companies have pioneered in gas fired, outdoor-type generating plants with their lower construction costs and the use of progressively larger generating units which incorporate the latest refinements in operating economy. If gas becomes too expensive or is more valuable for other purposes, there are large sources of lignite and coal in the Trinity River Basin that are available for power generation. Improvement of the Trinity River would afford low cost barge transportation for the movement of coal and lignite for thermal power generation and other uses. The most recent step which has been taken to assure Texans an adequate, dependable electric power supply at the lowest possible cost is the initiation of construction of a new interconnected super-transmission line. Four Texas utilities have joined to build the southwest's largest transmission line which will extend from the Red River to Houston, and west to the Permian Basin oil fields of West Texas as shown on figure 28. This 345,000-volt transmission line will link together six and one-half million kilowatts of electric power from the 27 steam-electric-generating plants of the four companies. It will be six times greater in electric power capacity than any other line now in operation in the Southwest and will form one of the largest and strongest reservoirs of power in the United States. Construction of the new "super power highway" will result in greater security of electric service throughout the area served because generating capability available in one area can be transmitted to other areas in the event of an emergency, or should a disaster cripple any local power system. Also, it will make additional power available to meet future power requirements of a number of REA Co-operatives. Since the interconnected companies will be able to install even larger generating units than those now in use, greater flexibility will be realized as to when additional generating equipment will be installed because of the ability to exchange power between systems. Consumptive water use for cooling requirements for projected thermal power generation in the basin is provided in the comprehensive plan.

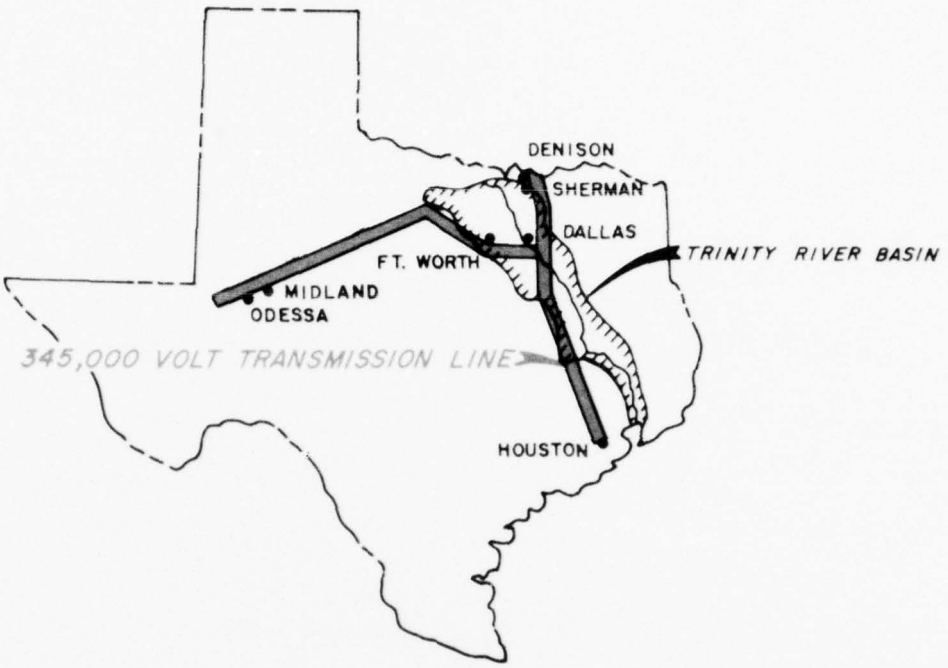


FIGURE 28

104. DRAINAGE.- The lack of adequate drainage restricts the optimum use of considerable acreage of agricultural lands in the Trinity River Basin. The Soil Conservation Service and the Corps of Engineers studied the magnitude of this problem in 1961 in connection with the U. S. Study Commission - Texas investigation. It was found that a drainage problem existed on about 1,570,000 acres, or 14 percent of the total land area in the basin. In addition, about 375,000 acres, mostly in Chambers and Liberty Counties, located just outside the basin near the mouth of the river have drainage problems. Within the basin, the slowly drained areas are relatively narrow bands paralleling the river and its principal tributaries.

105. The heavy black clay soils of the bottom lands have low permeability and are frequently inundated. Various obstructions, such as sediment, natural levees or flood debris, often block small tributary channels as well as the network of old river channels. Such obstructions cause ponding of floodwaters or runoff for extended periods and frequently result in high water tables. Local

drainage efforts in some parts of the basin have aggravated the drainage problem in downstream areas. At some points, drainage is blocked or slowed by roads and railroads. In most of the valley, the topography is virtually flat and runoff from higher lands concentrates in the numerous swales and pocket areas and creates high water tables. Most crops can tolerate only limited periods of waterlogging or inundation, usually not over 24 to 30 hours. The Coastal Prairie land used for rice production in Chambers and Liberty Counties just outside of the basin accounts for practically all of the slowly drained land that is now under cultivation.

106. Lands feasible for drainage.- Of the total land within the drainage problem areas of the basin, it was estimated that about 37,000 acres are now adequately drained and that drainage is feasible on about 449,000 additional acres, making a total of 486,000 acres or 31 percent of the total problem areas that has been or could be adequately drained. Of the 449,000 acres feasible for drainage, about 233,000 acres would require group drainage consisting of a system of lateral ditches to collect and carry farm drainage to the natural streams that usually serve as major outlets and about 158,000 acres would require improvement of the major outlets.

107. It is inevitable that many developments associated with industrialization, housing, commercial enterprise, and recreation will be made on lands now classed as agricultural, including some of the drainage problem areas. Such developments will remove these lands from the problem field of agricultural drainage but may intensify the drainage problem. With the construction of buildings, driveways, streets, sidewalks and other non-permeable areas of urban development, the more rapid runoff of rainfall frequently creates drainage problems in the areas of low elevation. Generally, the local communities and agencies of local government provide facilities for adequate drainage of problem areas within their jurisdiction.

108. Plans for future drainage.- Adequate surface drainage of agricultural wetlands requires a complete on-farm system of drains usually accompanied by construction of a group lateral collection and disposal system and enlargement and improvement of the major outlets. Generally, individual landowners are expected to provide the on-farm system. Local or state government agencies are expected to carry out detailed overall planning and provide the lateral collection and disposal system. The Soil Conservation Service upon request, may provide technical and financial assistance in planning and installation of works of improvement. With the specific authorization of Congress, the Corps of Engineers can plan and construct major outlet improvements in cooperation with local interests. As local drainage facilities are improved by local farmer groups and under Soil Conservation Service programs, it is probable that some of the major drainage

outlets will also require improvement. As such problems develop, it is expected that Congress, in accordance with established policy, will authorize the Corps of Engineers to investigate the individual problems and to plan and construct any necessary improvements. Although major drainage improvements are not proposed in this report, all proposed improvement works, including the navigation locks and dams, were planned with drainage in mind, so that the projects would not be detrimental to drainage and, wherever possible, would provide improved drainage conditions.

COMPREHENSIVE PLAN OF DEVELOPMENT

109. PLANNING CONSIDERATIONS.- The basic objective in the formulation of a plan of development for the Trinity River Basin is to provide the best use, or combination of uses, of the water and related land resources of the basin to meet all foreseeable short- and long-term needs. In planning for the best use of water and related land resources for a balanced program, the overriding determinant is the economic and social well-being of all of the people and the achievement of satisfactory levels of living. The development and control of water resources are planned on a fully comprehensive basis to include adequate supplies of water for municipal, agricultural, and industrial use; water quality facilities and controls to assure water of suitable quality for all purposes; water navigation facilities for needed transportation service; flood control measures; hydroelectric power; irrigation; drainage; watershed protection and management; outdoor recreation; and fish and wildlife protection and enhancement. Plan formulation studies require the consideration of all water problems and the interrelation of all purposes and projects to develop fully the potential of the basin.

110. Broad principles used in accomplishing the above are (a) that the elements of the plan for further control and development of the water resources of the basin would be integrated into the existing system so as to provide a balanced program; (b) that there is not a more economical means, evaluated on a comparable basis, of accomplishing the same purpose or purposes; (c) that the scale of development of each project be such as to provide the maximum excess benefits over costs insofar as practicable; and (d) that the adopted plan be capable of further expansion, as future conditions require such expansion. In addition to these broad principles, certain basic planning and design considerations for individual purposes are used in defining the final comprehensive plan of development. The more important of these basic planning and design considerations and objectives are: (1) that protection of urban areas against the standard project flood be provided if economically feasible; (2) that rural areas be afforded flood protection against a recurrence of the 50-year flood; (3) that navigation facilities should be provided in consonance with the pattern of existing and future economic development of the basin; (4) that full cognizance be given to the long-range waterflow retardation and land conservation program of the Soil Conservation Service; (5) that reservoir capacity for supplies of water be in consonance with the State of Texas' expressed policy for maximum practical development of the water resources of individual river basins; (6) that planning for supplies of water be in full agreement with existing water rights and priorities of use established by the State of Texas; (7) that future demands for supplies of water in the Trinity River Basin be satisfied insofar as practicable from

"in-basin" resources; and (8) that planning for water quality recognize the pollution problems associated with existing and future development and provide necessary measures to protect the health and welfare of the people.

111. DEVELOPMENT OF THE PLAN.- Several basic types of water control measures are considered in planning the development of the water and related land resources of the Trinity River Basin. Improvement measures include: (1) major impoundments of runoff for regulation and use in the general areas of need and to control flood flows and reduce damages in downstream areas; (2) land treatment measures, including detention structures and small impoundments in headwater and tributary reaches, to reduce flood flows and provide small pools of water for localized uses; (3) improvement of stream channels or construction of channels, ditches, and pipelines for such purposes as increasing the flood-carrying capacity of streams, providing channels adequate for navigation, draining agricultural wetlands, and providing carrying systems for transporting water to points of need; (4) levees, floodwalls, bank protective works, and other training measures to direct the flow of water for local flood protection and preserve the integrity of design flow channels; (5) locks and dams to create slackwater pools for barge navigation and provide a means of lifting and lowering vessel traffic to overcome the natural gradient of the river; (6) facilities for supplementing the available supply of surface water, such as development of ground water resources and importation of water from adjacent river basins; and (7) lands and facilities adjacent to water areas for public recreation and preservation and enhancement of fish and wildlife resources.

112. Many improvements for developing water resources in the basin have been constructed in past years by both Federal and non-Federal interests as shown on figure 1. The improvements have included all of the basic types listed above. Generally, however, the existing and under-construction facilities satisfy an immediate and, often localized, specific need. A comprehensive development plan must first weigh the effects of existing, under-construction, and definitely planned improvement measures against the total needs for all purposes; then, insofar as practicable, provide for additional improvements or modifications of existing facilities required to bring the overall program into balance and satisfy the present and future needs in the most economical manner.

113. EXISTING, UNDER-CONSTRUCTION, AND AUTHORIZED IMPROVEMENTS.- The existing Corps of Engineers reservoir program comprises six major projects, including four completed, one under-construction, and one authorized for construction. The Soil Conservation Service reservoir program provides for construction of 1,200 small flood detention

reservoirs in headwater and tributary areas, together with land treatment measures. A total of 288 small reservoirs have been completed, with the remainder to be completed before 2020. There are 107 reservoirs of all sizes that have been constructed or are under construction in the basin by various state and local government agencies and private concerns, including 18 which have storage capacities in excess of 5,000 acre-feet. The cities of Dallas and Terrell have made permanent arrangements with the Sabine River Authority for importing water from the Tawakoni (Iron Bridge) Reservoir on the Sabine River. The City of Athens has made similar arrangements for importing water from the Flat Creek Reservoir on the Neches River Basin. Imports from these sources are included as part of the comprehensive plan and are expected to total 172 million gallons per day in 2020 and 180 million gallons per day in 2070. The ground water resources within the basin were developed in 1958 to the extent of providing about 72 million gallons per day.

114. The Corps of Engineers reservoirs primarily provide flood control and water conservation storage, although two provide storage for navigation water and all of the completed reservoirs provide recreational facilities. For the most part, the non-Federal reservoirs provide water conservation storage; however, they are also used extensively for recreational purposes. Total storage available in all of the existing, under-construction, and authorized reservoirs is about 7.3 million acre-feet, about equally divided between the Federal and non-Federal reservoirs.

115. Three existing and authorized Corps of Engineers local flood protection projects will provide flood protection to portions of the cities of Fort Worth, Richland Hills, and Dallas. These projects include about 23 miles of improved channels and about 45 miles of levees, which form floodways through parts of the cities. In addition, 38 agricultural levee districts, organized under state laws, have flood protection levees in operation along the Trinity River and tributaries. There was no coordinated plan for these levees and they vary in height and size and afford varying degrees of protection to the lands protected. From time to time many of these agricultural levees have been damaged by major floods and have been restored by the Corps of Engineers under emergency flood damage repair authority.

116. The authorized project for navigation on the Trinity River provides for a 9x150-foot channel extending from the Houston Ship Channel through Galveston and Trinity Bays and the Trinity River to Liberty, Texas, a total distance of about 49 miles. The 23-mile reach extending through the bays from the Houston Ship Channel to Anahuac has been constructed but not maintained for several years. The channel was not extended into the Trinity River because of salt water intrusion problems. The existing Anahuac Channel is being maintained to provide navigation from Galveston Bay to the lower reaches of the Trinity River. The recently submitted report recommend-

ing construction of the Wallisville Reservoir also recommends a navigation lock at the dam and immediate construction of the authorized project channel upstream to mile 33.8 to connect with a spur channel owned by the Texas Gulf Sulphur Company.

117. PROJECTS RECENTLY RECOMMENDED IN SEPARATE REPORTS.- Because of urgent problems in local areas, separate reports have been submitted previously recommending enlargement of the Lavon Reservoir, near Dallas, and construction of the Wallisville Reservoir, near the mouth of the Trinity River. The Lavon enlargement would provide over 262,000 acre-feet of additional storage capacity for water conservation and recreational purposes. The recommended Wallisville Reservoir would serve several purposes, including prevention of salinity intrusion into irrigation water pumped from the lower river, water conservation, navigation, recreation, and fish and wildlife conservation. For water conservation the reservoir would be operated in combination with the Livingston Reservoir which is now under construction. Extension of the Fort Worth Floodway for a distance of about 8 miles on Clear Fork and channel improvement and rehabilitation of local levees along a 32-mile reach on East Fork have also been recommended in previously submitted reports.

118. ADDITIONAL IMPROVEMENTS REQUIRED.- The analysis of capabilities of existing, under-construction, and definitely planned improvements for development of water resources with respect to satisfying the existing and projected needs of the basin showed that additional improvements would be required. The analysis indicated serious deficiencies in satisfying both the immediate and long-range needs for flood control, navigation, and conservation of water for municipal and industrial water supply including water quality, recreation, fish and wildlife, power, drainage and irrigation. A comprehensive plan of development was prepared to include measures that would satisfy all of the foreseeable deficiencies. Irrigation development has been recognized in the proposed plan by inclusion of 356 MGD for irrigation requirements. No specific provisions for drainage are provided in the comprehensive plan although considerable work of this character is expected to be initiated by local interests with possible assistance from the Soil Conservation Service as the area develops. As this phase of development progresses, it is anticipated that studies by the Corps of Engineers will be authorized to investigate the necessity and justification of Federal participation in the construction of major drainage outlet facilities. The power requirements of the basin are expected to be generally supplied by the utility companies from thermal power generation as the need develops. Industrial water supply provided in the plan would include 570 MGD in the year 2020 for cooling requirements for the increased power generation. On this basis, improvements for irrigation, drainage, and power are not considered further in the comprehensive plan.

119. The remaining purposes to be satisfied in the comprehensive plan would require additional improvements to bring the overall system into balance and meet the present and future water and related land resources needs to the maximum practicable extent. The proposed additional improvements are separated into two categories: (1) projects in the long-range plan but not recommended for authorizations at this time, and (2) projects proposed for immediate Federal authorization, hereinafter referred to as the "Projects Recommended for Authorization." The projects included in the long-range plan, but not recommended for authorization at this time, comprise 13 reservoir projects required to satisfy the projected water requirements of the basin. It is probable that further developments may indicate needs for local adjustment or supplements to the comprehensive plan which, for the most part, can be accomplished with no loss in overall efficiency. It is anticipated that as the water requirements develop to the extent that these projects are required, further investigation will be made to assure that the developments would serve all purposes found desirable and justified at that time. The projects recommended for authorization are those improvements which, for various reasons, were found to be needed now and which, as a result of detailed analyses, were determined to be economically justified.

120. The projects in the comprehensive plan are shown on plate 1 and are summarized in tables 6 and 7. Table 6 presents pertinent data for reservoir projects in the plan and table 7 presents data for other improvements.

TABLE 6

COMPREHENSIVE PLAN - RESERVOIRS

Name	Owner	Location: Stream	Location: Mile	Total drainage area above (sq mi)	Total storage capacity (acre-feet)	Dependable yield in year 2020 MGD(1)	Purpose(2)
EXISTING, UNDER CONSTRUCTION AND AUTHORIZED							
FEDERAL RESERVOIRS							
Benbrook	Corps of Engineers	Clear Fork	15.0	433	258,600	6.5	FC-Con-Nav-R-F&W
Grapevine	Corps of Engineers	Denton Creek	11.7	694	435,500	18.1	FC-Con-Nav-R-F&W
Garza-Little Elm	Corps of Engineers	Elm Fork	30.0	1,658	1,002,900	86.0	FC-Con-R-F&W
Lavon	Corps of Engineers	East Fork	55.9	777	423,400	35.5	FC-Con-R-F&W
Navarro Mills(3)	Corps of Engineers	Richland Creek	63.9	316	212,200	18.1	FC-Con-R-F&W
Bardwell(3)	Corps of Engineers	Waxahachie Creek	6.0	171	117,800	4.2	FC-Con-R-F&W
1,200 Small detention res(4)	Soil Conservation Serv.	(Headwater & tributary areas throughout basin)		3,679(4)	1,301,966(4)	0	FC
NON-FEDERAL RESERVOIRS(5)							
Amon Carter	City of Bowie	Big Sandy Creek	31.0	103	19,900	0	Con
Bridgeport	Tarrant Co. WC&ID #1	West Fork	626.2	1,114	270,900	50.4	Con
Eagle Mountain	Tarrant Co. WC&ID #1	West Fork	583.3	1,974	182,600	(17.5	Con
Lake Worth	City of Fort Worth	West Fork	572.1	2,069	33,700	(	Con
Marine Creek	Tarrant Co. WC&ID #1	Marine Creek	4.7	10	15,400	0	FC-Con
Weatherford	City of Weatherford	Clear Fork	39.8	106	19,400	0.6	Con
Arlington	City of Arlington	Village Creek	8.0	136	45,700	5.8	Con
Mountain Creek	Dallas P&L Co.	Mountain Creek	4.1	289	24,200	0	Con
North Lake	Dallas P&L Co.	So. Fork - Grapevine Cr.	0.5	2.3	17,100	0	Con
White Rock	City of Dallas	White Rock Creek	12.0	99	12,300	1.9	Con
Forney(3)	City of Dallas	East Fork	31.8	1,074	490,000	58.8	Con
Tawakoni (Iron Bridge)(6)	Sabine River Authority	Sabine River	-	-	-	174.0	Con
Terrell	City of Terrell	Muddy Cedar Creek	9.8	13	8,300	0.6	Con
Trinidad	Texas P&L Co.	(7)	-	-	6,200	0	Con
Cedar Creek(3)	Tarrant Co. WC&ID #1	Cedar Creek	11.1	1,013	678,900	173.2	Con
Waxahachie	Ellis Co. WID #1	So. Prong - Waxahachie Cr.	0.5	31	13,500	1.9	Con
Halbert	City of Corsicana	Elm Creek	0.7	12	7,420	0	Con
Flat Creek (8)	City of Athens	Flat Creek	-	-	-	6.0	Con
Livingston (3)	Trinity River Authority	Trinity River	129.2	16,606	1,750,000	670.9	Con
Anahuac	Chambers & Liberty Co. Nav. Dist.	(9)	-	129	35,300	13.4	Con
RECOMMENDED FOR FEDERAL AUTHORIZATION IN PREVIOUSLY SUBMITTED REPORTS							
Lavon (enlargement)(10)	Corps of Engineers	East Fork	55.9	777	685,700	42.7(11)	FC-Con-R-F&W
Wallisville(12)	Corps of Engineers	Trinity River	3.9	17,760	55,700	(13)	Con-Nav-S-R-F&W
RECOMMENDED FOR FEDERAL AUTHORIZATION IN THIS REPORT							
Lakeview	Corps of Engineers	Mountain Creek	7.2	272	488,700	30.4	FC-Con-R-F&W
System (Roanoke	Corps of Engineers	Denton Creek	31.4	604	249,900	(23.9(14)	FC-R-F&W
System (Grapevine	Corps of Engineers	Denton Creek	11.7	-	-	(	FC-Con-Nav-R-F&W
System (Aubrey	Corps of Engineers	Elm Fork	60.0	682	899,900	(	FC-Con-R-F&W-Q
System (Garza-Little Elm	Corps of Engineers	Elm Fork	30.0	-	-	(65.3(15)	FC-Con-R-F&W
Tennessee Colony	Corps of Engineers	Trinity River	339.2	12,687	3,366,800	290.8	FC-Con-Nav-R-F&W-Q
RECOMMENDED FOR INCLUSION IN LONG RANGE PLAN BUT NOT FOR AUTHORIZATION AT THIS TIME							
Boyd	-	West Fork	604.7	1,707	639,200	31.7	(16)
Richland Creek	-	Richland Creek	5.2	714	1,045,200	169.3	(16)
Tehuacana	-	Tehuacana Creek	11.2	356	295,300	56.9	(16)
Upper Keechi	-	Upper Keechi Creek	11.0	486	134,500	54.3	(16)
Hurricane	-	Hurricane Bayou	7.0	91	151,900	17.5	(16)
Lower Keechi	-	Lower Keechi Creek	8.9	162	173,000	25.2	(16)
Bedias	-	Bedias Creek	19.2	327	376,700	94.4	(16)
Harmons	-	Harmons Creek	10.5	47	79,100	16.8	(16)
Gail	-	Gail Creek	25.3	91	169,900	31.0	(16)
Mustang	-	Mustang Creek	23.7	84	157,700	25.2	(16)
Caney	-	Caney Creek	7.7	74	135,600	25.2	(16)
Long King	-	Long King Creek	22.9	57	186,200	34.9	(16)
Capers Ridge	-	Trinity River	63.0	17,436	841,500	98.0	(16)

(1) Areal or primary yield in million gallons per day based on a recurrence of the 1950-1957 drought period under 2020 conditons of watershed development. For the projects where zero yield is shown these projects have been designed for watersned conditions other than year 2020 and for a period of runoff less critical than the recurrence of the 1950-1957 drought. (Does not include return flow)

(2) FC - Flood control
Con - Water supply
Nav - Navigation
R - Recreation
S - Salinity intrusion control
F&W - Fish and wildlife conservation
Q - Water quality control

(3) Under construction or authorized

(4) Totals for 1,200 reservoirs - 288 constructed, including 4 of greater than 5,000 acre-feet storage capacity.

(5) Only those reservoirs with total storage of 5,000 acre-feet or greater are listed.

(6) Import from Sabine River Basin for City of Dallas.

(7) Off-cnannel on left bank of Trinity River above mouth of Cedar Creek

(8) Import from Neches River Basin for City of Athens

(9) Off-channel - Turtle Bay

(10) Report not printed at this time

(11) Net increase in yield resulting from increased conservation storage

(12) House Doc. 215, 87th Cong., 1st Sess.

(13) Included with yield of Livingston

(14) Increase in yield as a result of exchange of storage with Roanoke

(15) Increase in yield from the Garza-Little Elm - Aubrey system

(16) Conservation with probable flood control and other purposes

TABLE 7

COMPREHENSIVE PLAN - OTHER IMPROVEMENTS

Project	Location: Stream or locality	Location: Mile to Mile		Type of improvement	Remarks
EXISTING, UNDER CONSTRUCTION AND AUTHORIZED					
LOCAL FLOOD PROTECTION PROJECTS					
Federal					
Fort Worth Floodway	Clear Fork	0	1.6	Channel improvement & levees	Existing
	West Fork	564.7	570.4	Channel improvement & levees	Authorized
	West Fork	551.3	564.7	Channel improvement & levees	Existing
Big Fossil Creek Floodway (City of Richland Hills)	Big Fossil Creek	0	3.3	Channel improvement & levees	Authorized
Dallas Floodway	Elm Fork	0	3.5	Channel improvement & levees	Existing
	West Fork & Trinity River	497.4	508.7	Channel improvement & levees	Existing
Non-Federal					
Agricultural levees	Trinity River and tributaries	-	-	Levees	Existing - 38 active local levee districts
FEDERAL NAVIGATION PROJECTS					
Trinity River, Channel to Liberty (9x150-foot channel)					
Houston Ship Channel to Anahuac	Galveston & Trinity Bays	0(1)	23.2(1)	Channel improvement	Constructed - not maintained
Anahuac to Liberty	Trinity River	23.2(1)	48.9(1)	Channel improvement	Authorized
RECOMMENDED FOR FEDERAL AUTHORIZATION IN PREVIOUSLY SUBMITTED REPORTS					
LOCAL FLOOD PROTECTION PROJECTS					
Fort Worth Floodway	Clear Fork	1.6	10.4	Channel improvement & levees	
East Fork Channel Improvement	East Fork	0	31.8	Channel improvement & levee rehab.	
RECOMMENDED FOR FEDERAL AUTHORIZATION IN THIS REPORT					
MULTIPLE-PURPOSE CHANNEL IMPROVEMENT					
Houston Ship Channel to Fort Worth	Trinity River & West Fork	0	369.8(2)	Channel enlargement, rectification, & navigation locks and dams	For navigation, flood control, recreation, and fish and wildlife
LOCAL FLOOD PROTECTION PROJECTS					
West Fork Floodway	West Fork	505.5	551.5	Channel improvement & levees	To connect Fort Worth & Dallas Floodways
Elm Fork Floodway	Elm Fork	0	29.4	Channel improvement & levees	Lower end connects with Dallas Floodway
	Denton Creek	0	11.1	Channel improvement & levees	
Dallas Floodway Extension	Trinity River	487.7	498.1	Channel improvement & levees	Downstream extension to Five-Mile Cr.
Duck Creek Channel Improvement	Duck Creek	10.4	17.5	Channel improvement	
Liberty Local Protection Project	Trinity River	34	44.5	Levees	

(1) Channel mile
(2) Channel mile - natural river mile 551.5

PROJECTS RECOMMENDED FOR AUTHORIZATION

121. INTRODUCTION.- To satisfy the existing and immediately prospective needs for additional flood protection, navigation, water supply including water quality, recreation, and fish and wildlife, a number of improvements are proposed for immediate authorization and construction. A multiple-purpose channel improvement is proposed from the Houston Ship Channel to Fort Worth to provide for barge navigation and to provide sufficient channel capacity to contain flood discharge releases from flood control storage in upstream reservoirs and partial control of runoff downstream from the reservoirs. A system of dams would provide a series of slackwater pools and navigation locks would lift and lower vessel traffic between these pools. The navigation pools would afford recreation and fish and wildlife benefits. Four reservoirs are proposed consisting of Roanoke (including modification of Grapevine) on Denton Creek, Aubrey (including modification of Garza-Little Elm) on Elm Fork, Lakeview on Mountain Creek, and Tennessee Colony on the main stem of the Trinity River with a wildlife refuge in Tennessee Colony and water quality control distribution facilities from Tennessee Colony Reservoir to the existing Benbrook Reservoir. In conjunction with the multiple-purpose channel improvement, levee improvements are proposed to extend and connect the Fort Worth and Dallas Floodways on the West Fork and to extend the Dallas Floodway downstream to Five Mile Creek, and to provide flood protection to the City of Liberty, Texas. Levees and channel improvements are proposed on Elm Fork to provide a floodway extending from its mouth upstream to about Carrollton, with improved channels extending further upstream to the Garza-Little Elm Reservoir and on Denton Creek to Grapevine Reservoir. A channel rectification project is proposed on Duck Creek for the protection of the City of Garland.

122. MULTIPLE-PURPOSE CHANNEL.- The proposed multiple-purpose channel would begin at the Houston Ship Channel, near Red Fish Bar, in Galveston Bay, follow the authorized Channel to Liberty project through Trinity Bay and the Trinity River to the City of Liberty, and continue along the general course of the Trinity River to the Riverside Drive bridges in Fort Worth, a total distance of about 370 miles. Spur channels would extend to turning basins at Dallas and Fort Worth. The channel would pass through the Wallisville, Livingston, and proposed Tennessee Colony Reservoirs.

123. It was determined early in the investigation that with a joint-use channel for flood control and navigation, the requirements for flood control would generally establish the final channel dimensions. The minimum dimensions of the channel for navigation are a depth of 12' and bottom width of 150' in the reach below Dallas, and a depth of 12' and width of 125' between Dallas and Fort Worth. As shown in table 8, the bottom widths and depths for the multiple-purpose channel required for

conveyance of the recommended channel capacity for flood control are generally in excess of the navigation requirements cited above. The proposed channel alignment provides for numerous cutoffs across natural bends of the river and for numerous straightened and rectified reaches of the channel. This realignment was generally dictated by requirements for navigation. The overall distance from the mouth of the river to Fort Worth along the improved channel would be about 345 miles, compared with the natural river distance of 552 miles. The plan and profile of the proposed multiple-purpose channel are shown on plate 2.

TABLE 8

DIMENSIONS AND CAPACITY OF MULTIPLE-PURPOSE
TRINITY RIVER CHANNEL

Channel mile		Length	Bottom	Depth	Recommended operating discharge	Recommended channel capacity
From	To	(miles)	width(ft)	(ft)(1)	(cfs)	(cfs)
0.0	28.30	28.30	150	13.3	Tidal pool	
			Wallisville Reservoir			
35.50	43.50	8.00	300	27.0	35,000	45,000
43.50	55.70	12.20	350	30.0	35,000	45,000
55.70	74.85	19.15	200	34.0	35,000	45,000
74.85	100.88(2)	26.03	150	40.0	35,000	45,000
			Livingston Reservoir			
147.92	234.60(3)	86.68	150	45.0	35,000	45,000
			Tennessee Colony Reservoir			
274.51	293.00	18.49	200	25.0	25,000	32,000
293.00	304.00	11.00	150	28.0	25,000	32,000
304.00	331.31	27.31	150	26.0	20,000	27,000
331.31	337.30	5.99	150	26.0	20,000	25,000
337.30	342.51	5.21	150	26.0	12,000	15,000
342.51	360.17	17.66	200	26.0	12,000	15,000
360.17	367.83	7.66	150	26.0	12,000	15,000
367.83	369.78	1.95	200	26.0	12,000	15,000

(1) Approximate depth of channel below top of river bank.
(2) Upper end of flood release discharge channel at the Livingston spillway basin.
(3) Upper end of flood release discharge channel at the Tennessee Colony spillway basin.

124. The multiple-purpose channel also provides 17 gated navigation dams and one overflow navigation dam in addition to the Wallisville, Livingston and Tennessee Colony Dams to provide slackwater pools for navigation. In conjunction with this system of dams, 23 locks would be required for passage of traffic. Tandem locks at Livingston and Tennessee Colony to accommodate the high lifts account for the two additional locks. The 19 locks located below the Dallas terminus would have clear basins 84 feet wide by 600 feet long. This size lock was selected as most efficient to lock the average barge tow of three barges and one towboat that would be necessary to carry the prospective commerce on this section of the waterway, together with pleasure craft, and which would have a minimum water requirement. The four locks between Dallas and Fort Worth would have clear basins 56 feet wide by 400 feet long. This size lock would accommodate the two barge tows necessary to carry the prospective commerce above Dallas and would involve a minimum demand on the available water supply in this reach. All of the gated navigation dams would consist of non-submersible tainter gates, 40 feet long, with sills set at the bottom elevation of the multiple-purpose channel at each dam site. The number of gates at each dam was determined by the capacity of the channel at that point. The proposed locations and pertinent data for the navigation locks and dams are shown in table 9.

TABLE 9

PERTINENT DATA CONCERNING SYSTEM OF LOCKS AND DAMS
PROPOSED FOR THE MULTIPLE-PURPOSE
TRINITY RIVER CHANNEL TO FORT WORTH, TEXAS

Location Lock and Dam (1)	Proposed lock: Lock No	Normal Pool elev (2): Lower	Upper	Lift (feet)	Proposed dam: Elevation: 2 percent flow (3)	Sill elevation(2)	Number & size of gates
28.30	1	0	4	4	5.0	-16.0	4-40X21
47.45	2	4	16	12	17.0	-13.0	7-40X31
59.08	3	16	36	20	37.0	3.5	6-40X34.5
74.85	4	36	60	24	61.0	26.0	6-40X36
98.00	5A	60	101	41	(4)		
99.20	5B	101	131	30	(4)		
147.92	6	131	138	7	139.0	96.0	5-40X44
183.92	7	138	168	30	169.0	126.0	5-40X44
207.55	8	168	192	24	193.0	152.0	5-40X42
217.95	9	192	210	18	211.0	166.0	6-40X46
233.00	10A	210	235	25	(5)		
233.61	10B	235	262.5	27.5	(5)		
258.91	11	262.5	270	7.5	(6)		
274.51	12	270	284	14	286.0	258.0	5-40X28
286.64	13	284	308	24	309.0	278.0	6-40X32
298.38	14	308	326	18	327.0	302.0	5-40X26
306.31	15	326	344	18	345.0	322.0	5-40X24
311.25	16	344	356	12	357.0	331.0	5-40X27
317.81	17	356	372	16	373.0	344.0	5-40X30
331.31	18	372	396	24	397.0	363.5	5-40X34.5
342.51	19	396	424	28	425.0	402.0	6-40X24
351.91	20	424	452	28	451.0	426.0	6-40X28
360.17	21	452	480	28	481.0	451.0	6-40X31

(1) Distance in channel miles from the Houston Ship Channel.
(2) Elevation in feet above mean sea level.
(3) Elevation of two percent flood discharge (regulated) in feet above mean sea level.
(4) Livingston Reservoir spillway controls river flows passing locks 5A and 5B.
(5) Tennessee Colony Reservoir spillway controls river flows passing locks 10A and 10B.
(6) Notched overflow spillway at lock No. 11.

125. All locks except Nos. 5A, 6, 10B and 11 and the Wallisville Reservoir lock would have massive concrete gravity-type walls founded on piling and would have concrete paved floors in the lock basin. Locks Nos. 5A, 6, 10B and 11 would be of concrete "U-Frame" type construction and would rest directly upon a natural foundation. The Wallisville Reservoir lock would provide a lock chamber, 84 feet wide by 600 feet long, in lieu of the 56 x 400-foot lock recommended in the plan for the Wallisville Reservoir project, contained in House Document No. 215, 87th Congress, 1st Session. The lock would have massive concrete gravity-type walls founded on wood piling, with a paved earth basin and timber mooring walls throughout the basin. All lock gates would be of the miter type except the sector gates at Wallisville. The sills would be set a minimum of 15 feet below normal pool elevations. Lock and Dam No. 3 would be located a short distance below the site of the proposed Capers Ridge Reservoir dam and could serve as part of the lock system for passing the dam when it is constructed. Except for the tandem locks required to pass the Livingston and Tennessee Colony dams, the shortest travel distance between locks would be about 5 miles and the longest would be about 49 miles in the Livingston Reservoir.

126. Bridges, highways, railroads and utilities.- All bridges over the proposed multiple-purpose channel would provide a minimum vertical clearance of 50 feet above the water surface elevation of the regulated flood discharge that would not be exceeded over two percent of the time. All bridges below Dallas would have a minimum horizontal clearance of 250 feet between bridge fenders and all bridges above Dallas would have a minimum clearance of 225 feet between fenders. All bridges extending across floodway projects would have a minimum vertical clearance of three feet above the design flood discharge water surface elevation of the floodway. High-level fixed bridges are proposed for all highways crossing the navigation channel. A total of 44 new and modified high-level highway bridges would be required, including the bridges on U. S. Highway 190 crossing the Livingston Reservoir and those on U. S. Highway 287 and State Highway 31 crossing the Tennessee Colony Reservoir. In addition to the high level bridges crossing the navigation channel, a new bridge to replace the existing First Street bridge and modification of the Beach Street and the two Riverside Drive bridges in Fort Worth would be required to provide adequate floodway clearances in the proposed floodway reach upstream from the Fort Worth navigation terminus. Vertical lift bridges are proposed for all railroad crossings of the multiple-purpose channel. A total of 13 new or modified railroad bridges would be required to provide for navigation on the project channel, including modification of the St Louis - Southwestern Railway crossing the Tennessee Colony Reservoir, four new life bridges over land-cut channel sections and eight modifications of existing railroad bridges.

127. The multiple-purpose channel would require the relocation of 111 pipelines of various sizes, ranging from 3 inches to 30 inches in diameter; 31 electric power transmission lines; 17 communication lines; 6 water lines ranging from 24 inches to 72 inches in diameter; and 6 sewer lines ranging from 18 inches to 84 inches in diameter.

128. Public-use areas.- The plan for the multiple-purpose channel improvement provides for the development of 31 public-use areas to be located adjacent to the channel. The proposed development includes twenty-one 50-acre sites, one 75-acre site and nine 125-acre sites with necessary access and internal roads, requiring a total land area of about 2,600 acres.

129. Aids to navigation.- The Commander, Eighth Coast Guard District, New Orleans, Louisiana, estimated the number and cost of aids to navigation for the multiple-purpose channel to Fort Worth. Generally, the aids would include single pile day beacons along the channel and radar-reflecting buoys in the Livingston and Tennessee Colony Reservoirs.

130. Lands required.- Lands required for the multiple-purpose channel include rights-of-way for the channel, lock and dam sites, access roads and public-use areas; spoil areas for maintenance and construction of the project and damages for severed lands that would be isolated by the channel. Channel rights-of-way include areas to be excavated and a 50-foot berm on each bank of the channel. Spoil area requirements are based on the assumption that dragline-excavated material will be spoiled to an average height of 15 feet and hydraulically excavated material will be spoiled to an average height of 5 feet. The land area requirements for the proposed multiple-purpose channel improvement total 45,400 acres, including 4,200 acres in fee simple for lock and dam sites, access roads and public use areas and 41,200 acres in easements for channel excavation, spoil disposal areas and severed lands.

131. LAKEVIEW RESERVOIR.- The Lakeview dam site is located at river mile 7.2 on Mountain Creek, about 3.1 miles above the existing Mountain Creek Dam. The reservoir would be formed by an earth-fill dam with a maximum height of 91 feet above the streambed and a total length of 22,620 feet, including a concrete spillway 136 feet long. The spillway, with a net opening of 120 feet and located in a saddle on the right abutment, would be a gate-controlled, ogee, flip-bucket type with three 40 by 28-foot tainter gates. The outlet works would consist of one 12-foot diameter conduit controlled by two $5\frac{1}{2}$x12-foot gates.

132. The reservoir would have a total controlled storage of 488,700 acre-feet and a water surface area of 15,650 acres at elevation 528.0, the top of the flood control pool. At elevation 518.0, the top of the conservation pool, the reservoir would have an area of 12,300

acres and a storage capacity of 349,500 acre-feet. The total allowance for a 100 year accumulation of sediment would be 45,600 acre-feet. The total conservation storage would be sufficient to provide a dependable yield of 30.4 million gallons per day under 2020 conditions of watershed development during a recurrence of the severest drought of record. Land requirements for construction of the dam and operation of the reservoir for the several purposes would be about 19,600 acres in fee simple and 800 acres in flowage easements. Additional lands required in fee simple for public use and access would be about 760 acres.

133. Construction of the Lakeview Reservoir would require relocation of 9.7 miles of farm to market highways, 12.0 miles of county roads, 1.5 miles of railroad, 1.5 miles of pipelines, 33.0 miles of telephone lines and 40.4 miles of electric power and distribution lines. There are no known cemeteries or significant mineral deposits in the proposed reservoir area. Portions of two unincorporated sub-divisions are located within the limits of the proposed reservoir.

134. TENNESSEE COLONY RESERVOIR.- The Tennessee Colony dam site is located at river mile 339.2 on the Trinity River, about 16 miles west of Palestine, Texas. The reservoir would lie in parts of Anderson, Freestone, Henderson and Navarro Counties. The dam would be an earth-fill structure with maximum height above the streambed of 114 feet and a total length of 29,500 feet, including a controlled concrete spillway 520 feet long. The concrete ogee spillway, located in a natural saddle near the left abutment, would be controlled by 11 tainter gates, each 40 feet wide and 35 feet high, providing a total net width of opening of 440 feet. The outlet works would consist of four sluices in the spillway piers, each 3 feet by 6 feet, with power operated slide gates. Navigation locks numbered 10-A and 10-B would be located near the right abutment of the dam.

135. The reservoir would have a total controlled storage of 3,366,800 acre-feet and a water surface area of 119,500 acres at elevation 285.0, the top of the flood control pool. At elevation 262.5, the top of the conservation pool, the reservoir would have an area of 73,540 acres and a storage capacity of 1,193,000 acre-feet. The total allowance for a 100-year accumulation of sediment would be 190,000 acre-feet. The total conservation storage is estimated to have a dependable yield of 290.8 million gallons per day under 2020 conditions of watershed development during a recurrence of the severest drought of record.

136. Initially the water conservation storage would serve in a dual capacity to provide dilution water for water quality control and to supply yield for municipal and industrial purposes in the middle basin. Eighty million gallons per day would be used for water quality requirements in the West Fork of the Trinity River. The water from Tennessee Colony would be conveyed about 98 miles to Benbrook Reservoir

through an 84-inch diameter pipeline with appurtenant pumping facilities. Benbrook Reservoir would be used for reregulation of this water without requirement for reallocation of or encroachment on existing storage allocations. Use of the storage capacity in Tennessee Colony and the pipeline facilities initially allocated to water quality control would be converted to municipal and industrial use in the upper basin as the needs for water supply develop and local interests contract for repayment of the remaining cost of the storage capacity and pipeline facilities. The remaining yield in Tennessee Colony of 210.8 million gallons per day would be used initially to meet the needs of the middle basin with gradual conversion to municipal and industrial uses in the upper basin as the needs develop and additional projects are constructed in the middle basin. Ultimately the total yield from Tennessee Colony would be used for municipal and industrial uses in the upper basin.

137. In connection with the Tennessee Colony Reservoir, the Bureau of Sport Fisheries and Wildlife recommends establishment of a National Wildlife Refuge to be located east of the Trinity River in Henderson and Anderson Counties. The proposed refuge would comprise about 21,000 acres located east of the proposed multiple-purpose channel between U. S. Highway 287 on the south and State Highway 31 on the north. The refuge would extend about 9 miles along the river and would average slightly less than 4 miles in width. The Bureau recommends, in accordance with the provisions of Public Law 85-624, 85th Congress, approved August 12, 1958, that the Corps of Engineers be authorized to acquire about 600 acres of land, in addition to about 20,400 acres required for other purposes of the reservoir, and to make the total 21,000 acres available to the Secretary of the Interior for refuge use, as provided for in Section 3 of the Fish and Wildlife Coordination Act cited above. The Bureau proposes to manage the refuge to provide controlled public hunting and to permit fishing at periods when it would not interfere with wildlife management.

138. Land requirements for construction of the dam and operation of the reservoir for the several purposes would be about 166,244 acres in fee simple and about 7,000 acres of flowage easements. Additional lands acquired in fee simple for public use and access would be about 1,907 acres. An additional 600 acres is recommended by the Bureau of Sport Fisheries and Wildlife for acquisition in fee simple for the proposed National Wildlife Refuge.

139. Construction of the Tennessee Colony Reservoir would require relocation of 21 miles of highways, 10 miles of county roads, 1.8 miles of railroads, 44 miles of pipelines and 21 miles of electric power lines. There are no known cemeteries in the proposed reservoir area. An allowance has been made for mineral subordination of known mineral deposits including the Cayuga oil field near Trinidad in the headwater area of the reservoir and three other small producing fields.

140. AUBREY RESERVOIR (INCLUDING MODIFICATION OF GARZA-LITTLE ELM RESERVOIR).- The Aubrey dam site is at mile 60.0 on the Elm Fork of the Trinity River in northeast Denton County. The site is between the towns of Sanger and Aubrey and is 30 river miles upstream from the Lewisville Dam (Garza-Little Elm Reservoir). The reservoir would be formed by an earth-fill dam with a maximum height of about 116 feet above the streambed and a total length of about 13,660 feet, including a concrete spillway 424 feet long. The spillway, with a net controlled opening of 360 feet located on the right bank, would be a concrete ogee section with nine 40 by 35-foot tainter gates. The outlet works would consist of two 36-inch diameter conduits through the spillway piers controlled by power operated slide gates.

141. The reservoir would have a total controlled storage of 899,900 acre-feet and a water surface area of 30,750 acres at elevation 635.0, the top of the flood control pool. At elevation 625.5, the top of the conservation pool, the reservoir would have an area of 24,340 acres and a storage capacity of 639,000 acre-feet. The total allowance for a 50-year accumulation of sediment would be 37,800 acre-feet. The flood control storage in the Aubrey Reservoir would permit a reallocation of storage in the Garza-Little Elm Reservoir to increase the storage presently allocated to water conservation in that reservoir. Under 2020 conditions of watershed development and recurrence of the severest drought of record, the dependable yield of the proposed Aubrey and Garza-Little Elm Reservoir system would be 151.3 million gallons per day, or an increase of 65.3 million gallons per day over that of the Garza-Little Elm Reservoir alone. The water conservation storage would serve in a dual capacity, operating initially to provide dilution water for water quality control, with gradual conversion to municipal and industrial use as those needs develop. Land requirements for construction of the Aubrey Dam and operation of the reservoir would be about 37,700 acres in fee simple and 1,500 acres in flowage easements. Additional lands acquired in fee simple for public use and access in the Aubrey and Garza-Little Elm Reservoirs would be about 4,200 acres.

142. Construction of the Aubrey Reservoir would require relocation of 16 miles of highways, 6 miles of county roads, 5 miles of railroads, 1 mile of pipeline, 10 miles of telephone lines and 12 miles of electric power lines. There are no known cemeteries or significant mineral deposits in the proposed reservoir area.

143. ROANOKE RESERVOIR (INCLUDING MODIFICATION OF GRAPEVINE RESERVOIR.- The Roanoke dam site is located at stream mile 32.0 on Denton Creek, about one mile northwest of the town of Roanoke. The dam would be near the upper limits of the existing Grapevine Reservoir. The reservoir would be formed by an earth-fill dam with a maximum height of about 97 feet above the streambed and a total length of about 15,200 feet, including a concrete spillway 328 feet long and two dikes. The spillway, with a net controlled opening of 280 feet, would be a concrete

ogee section with seven 40 by 35-foot tainter gates. The outlet works would consist of one 15-foot diameter conduit controlled by three 4.5 by 15-foot power operated slide gates.

144. The reservoir would have a total controlled storage of 249,900 acre-feet, including 223,700 acre-feet for flood control and 26,200 acre-feet sediment reserve. At elevation 619.0, the top of the flood control pool, the reservoir would have a water surface area of 9,720 acres. The reservoir would be operated for flood control only and no permanent impoundment of water would be made since impoundment in this reservoir would reduce the total yield of the watershed because of evaporation from the increased exposure of water surface. The flood control storage provided in Roanoke Reservoir would permit reallocation of storage in the existing Grapevine Reservoir to increase the conservation storage from the existing total of 161,250 acre-feet to a new total of 372,200 acre-feet. The dependable yield of Grapevine Reservoir, under 2020 conditions of watershed development and recurrence of the severest drought of record, would be increased from 18.1 million gallons per day to 42 million gallons per day. Land requirements for construction of the Roanoke Dam and operation of the reservoir for flood control would be about 710 acres in fee simple and about 11,990 acres of flowage easements. An additional 1100 acres of land, 600 acres converted from easement to fee and 500 acres in fee, would be acquired at the Grapevine Reservoir for public use and access.

145. Construction of the Roanoke Reservoir would require relocation of 12.1 miles of highways, 1 mile of county road, 4.5 miles of railroads, 5 miles of pipelines, 10 miles of telephone lines and 15 miles of electric power lines. There are no known cemeteries or significant mineral deposits in the proposed reservoir area.

146. LOCAL FLOOD PROTECTION PROJECTS.- In addition to flood control protection provided by the multiple-purpose channel improvement and the reservoir projects, it was found necessary and economically justified to afford protection from the standard project flood to 5 urban localities by means of local flood protection projects. It was found necessary, also, to improve the channels below the Garza-Little Elm and Grapevine Reservoirs to provide channel capacities consistent with a sound flood control regulation plan that would allow emptying the reservoir flood storage pools within periods ranging from 30 to 40 days. The local protection projects would include the appurtenant facilities and necessary measures to preserve the drainage of protected areas and carry drainage water through the levees. Such facilities and measures include permanent ponding areas, gated gravity sluices and conduits, enlargement and realignment of tributary channels through the leveed areas, and filling of some low areas with excess excavated materials from channel improvements. Also included in the local protection projects are alteration or reconstruction of bridges crossing

the floodway to provide adequate clearances and necessary alteration or relocation of highways, streets, railroads, pipelines and utility lines.

147. West Fork Floodway.- The proposed West Fork Floodway improvement would extend about 31 channel miles up the West Fork to connect and provide a floodway from the upper end of the Dallas Floodway at Elm Fork to the lower end of the Fort Worth Floodway. The channel improvement in this reach would consist of the multiple-purpose channel for navigation, flood control and other purposes. Levees would provide a floodway width varying from about 1,000 feet to 3,000 feet. About 8,430 acres of land would be required for rights-of-way for the proposed improvements.

148. Elm Fork Floodway.- The proposed Elm Fork Floodway would connect with the Dallas Floodway at the confluence of Elm Fork and West Fork. Channel rectification and enlargement and a leveed floodway to afford standard project flood protection would be provided from the Dallas Floodway upstream along Elm Fork to the mouth of Denton Creek, a distance of about 14.3 channel miles. Channel rectification and enlargement only would extend from that point upstream along Elm Fork to the Lewisville Dam outlet works and upstream along Denton Creek to the outlet works of the Grapevine Dam to provide adequate channel capacity for the proper regulation of those projects for flood control. The total improved length along Elm Fork would be about 21.8 miles and along Denton Creek about 8.9 miles. The floodway along Elm Fork would have a minimum width between levees of about 1,100 feet. About 3,400 acres of land would be required for rights-of-way for the proposed improvements.

149. Extension of Dallas Floodway.- The proposed downstream extension of the Dallas Floodway would provide additional floodway length of about 9.7 miles along the Trinity River and would terminate at the mouth of Five Mile Creek. The channel improvement would comprise the multiple-purpose channel in this reach. Levees would provide a minimum floodway width of about 2,000 feet. About 4,030 acres of land for rights-of-way would be required for the proposed improvements.

150. Duck Creek Channel Improvement.- A reach of Duck Creek between stream miles 10.4 and 17.5 at Garland, Texas, would be realigned and enlarged to provide sufficient within-banks capacity to contain the standard project flood. About 190 acres of rights-of-way would be required for construction of the improved channel and disposal of the excavated materials.

151. Liberty Local Protection Project.- About 10 miles of levees would be provided along the left bank of the Trinity River in conjunction with the multiple-purpose channel to protect the City of Liberty, Texas. The levees along the river would be located from 600 to 6,000 feet from the multiple-purpose channel and would protect areas on the north and

south of the city. About 6 miles of the levees would be constructed by controlled spoiling of hydraulically dredged material from the multiple-purpose channel. Two pumping stations with capacities of 40,000 and 150,000 gallons per minute would be provided for interior drainage of the north and south leveed areas, respectively, during periods of high river stages. About 560 acres of rights-of-way would be required for construction of the levees and about 500 acres of flowage easements would be required for ponding areas for interior drainage. Relocation or alteration of 9 oil pipelines, one sewer line and one telphone line would be required.

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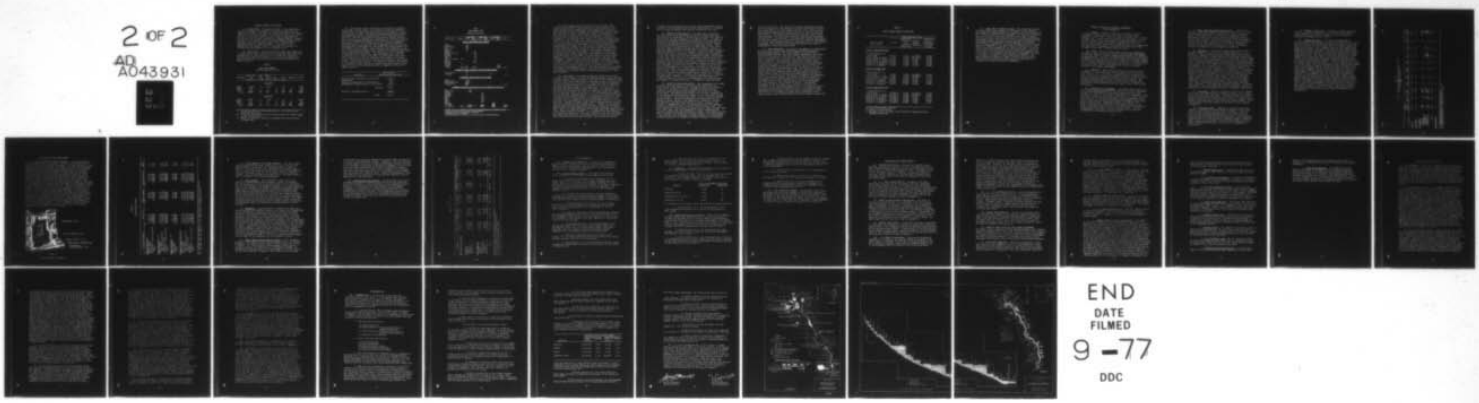

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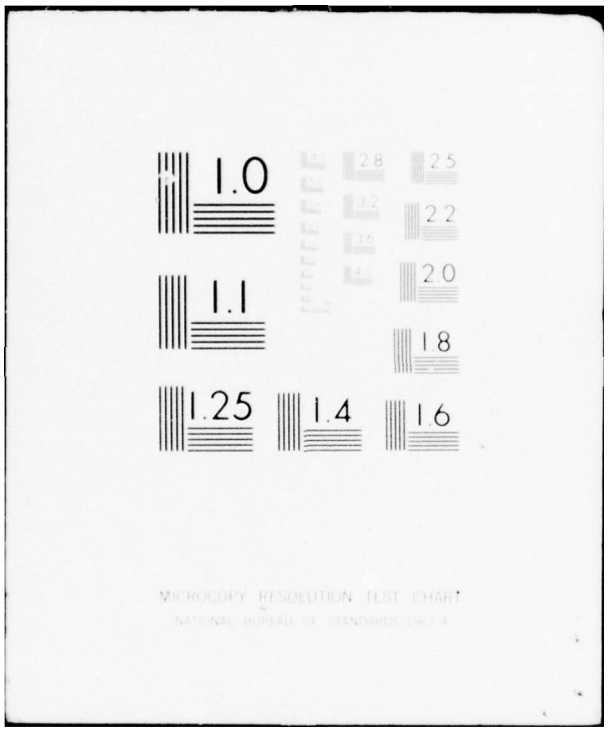
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PHYSICAL EFFECTS OF THE PLAN

152. INTRODUCTION.- The physical effects of the comprehensive plan of development were evaluated to determine the ability of all elements of the plan to satisfy various water and related land resource needs of the Trinity River Basin. It has been pointed out in previous sections of this report that provision of works of improvement for certain needs such as land stabilization, drainage measures, irrigation and power will be handled through existing programs, separate authorizations or by other alternative means such as thermal-electric generating plants for power development. The results of the evaluation of the physical effects of the plan for satisfying the residual needs are summarized in the paragraphs below.

153. WATER SUPPLY.- The projected water supply requirements for the Trinity River Basin to satisfy the needs for municipal, industrial, non-municipal use, water quality control, navigation, irrigation, and exportation have been estimated to be 3,433 million gallons per day by year 2020 and 5,187 million gallons per day by year 2070, as shown in table 10.

TABLE 10

WATER REQUIREMENTS
(Million Gallons Per Day)

Sub-basin	Municipal and Industrial	Non-Municipal	Water quality control	Navigation	Irrigation	Export(3)	Total
			Year 2020				
Upper	1,513(1)	15	80(2)	0	69	0	1,677
Middle	227	3	0	0	65	0	295
Lower	340	2	0	57	222	840	1,461
Total	2,080	20	80	57	356	840	3,433
			Year 2070				
Upper	2,797	11	0(2)	0	69	0	2,877
Middle	435	4	0	0	65	0	504
Lower	686	1	0	57	222	840	1,806
Total	3,918	16	0	57	356	840	5,187

(1) Includes 40 MGD yield from Aubrey Reservoir for interim use as water quality control.
(2) 80 MGD for water quality control would be converted to water supply as the need develops.
(3) Export to the City of Houston in accordance with the provisions of Permit 1970.

154. The existing, under construction, and authorized reservoirs with storage for water supply for municipal and industrial purposes together with the importations would produce a water supply of 1,343.4 million gallons per day. The Roanoke (including modification of Grapevine Reservoir), Aubrey (including modification of Garza-Little Elm Reservoir), Lakeview, and Tennessee Colony multiple-purpose reservoir projects which are recommended for authorization in this report plus the previously recommended enlargement of Lavon Reservoir would produce a water supply of 453.1 million gallons per day. Thirteen additional potential reservoir projects have been recommended for inclusion in the long-range plan of development for the Trinity River Basin primarily in the interest of water supply. These reservoirs were formulated on the basis of developing the surface water resources of the Trinity River Basin to the maximum practical extent. The construction of the long-range projects has been considered as a phase development which would be coordinated with the needs of the basin in such a manner as to permit timely construction to provide additional water supply as the needs develop. The thirteen potential reservoirs would produce a water supply of 680.4 million gallons per day. The system of reservoirs included in the comprehensive plan together with importations would furnish a water supply of 2,476.9 million gallons per day as summarized below and as shown in table 11.

Reservoirs	Water Supply (Million gallons per day)
Existing, Under construction, Authorized	1,163.4
Importations	180.0
Previously recommended for authorization	42.7
Recommended for authorization in this report	410.4
Sub-Total	1,796.5
Potential long-range projects	680.4
Total	2,476.9

TABLE 11

PRIMARY RESERVOIR YIELDS

(million gallons per day)(1)

Reservoir project	Imports	Upper basin: Federal	Upper basin: Non-Federal	Middle basin: Federal	Middle basin: Non-Federal	Lower basin: Federal	Lower basin: Non-Federal	Total
EXISTING, UNDER CONSTRUCTION AND AUTHORIZED								
Benbrook		6.5						
Grapevine		18.1						
Garza-Little Elm		86.0						
Lavon		35.5						
Navarro Mills		18.1						
Bardwell		4.2						
Bridgeport			50.4					
Eagle Mtn & Lake Worth			17.5					
Weatherford			0.6					
Arlington			5.8					
White Rock			1.9					
Forney			58.8					
Tawakoni (Iron Bridge)	174.0							
Terrell			0.6					
Cedar Creek			173.2					
Waxahachie			1.9					
Flat Creek	6.0							
Livingston						670.9		
Anahuac						13.4		
Total	180.0	168.4	310.7			684.3		1,343.4
RECOMMENDED FOR FEDERAL AUTHORIZATION IN PREVIOUSLY SUBMITTED REPORTS								
Lavon (enlarged)		42.7						
Wallisville						(4)		
Total		42.7						42.7
RECOMMENDED FOR FEDERAL AUTHORIZATION IN THIS REPORT								
Lakeview		30.4						
Roanoke-Grapevine		23.9(2)						
Aubrey-Garza-Little Elm		65.3(3)						
Tennessee Colony		290.8						
Total		410.4						410.4
RECOMMENDED FOR INCLUSION IN LONG RANGE PLAN BUT NOT FOR AUTHORIZATION AT THIS TIME(5)								
Boyd		31.7						
Richland Creek		169.3						
Tehuacana		56.9						
Upper Keechi				54.3				
Hurricane				17.5				
Lower Keechi				25.2				
Bedias				94.4				
Harmons				16.8				
Gail				31.0				
Mustang				25.2				
Caney				25.2				
Long King						34.9		
Capers Ridge						98.0		
Total		257.9		289.6		132.9		680.4
Total by basins	180.0	1,190.1		289.6		817.2		2,476.9

(1) Based on recurrence of 1950-1957 critical dry period under 2020 conditions of watershed development.
(2) Increase yield as a result of exchange of storage with Roanoke.
(3) Increase yield from the Aubrey-Garza-Little Elm system.
(4) Included with yield of Livingston.
(5) Authorization studies will be required to determine the extent of Federal participation.

155. Water supply from reservoirs which are existing, under construction, authorized, and recommended for authorization in this report together with a nominal use of ground water and return flow would satisfy the projected demands in all segments of the basin until about year 2000 to 2010. An additional supply of approximately 1,640 and 3,390 million gallons a day would be required to satisfy the projected water requirements for years 2020 and 2070, respectively. An analysis of the available water supply in the basin from additional reservoirs in the long range plan, ground water and return flow revealed that the potential of these resources may be sufficiently developed to satisfy the additional requirements of the basin to year 2070. Unquestionably the expansion of ground water use beyond the present 72 million gallons per day, the use of return flows, and construction of additional reservoirs will progressively increase throughout the projected period of basin development. Other than to conclusively establish the fact that ultimate water requirements will necessitate the maximum practical development of these resources to meet in-basin demands, no definitive basis is available to predict just when the development of these resources would be scheduled. Also water from alternative sources of supply in adjacent basins to the north and east could be imported if in the future local interests or the State decided to utilize such resources rather than to use in-basin resources. Generally, the development and use of these water resources will progress in consonance with changing economic conditions and areal development of the basin and with the distribution, availability and quality of these water resources.

156. Development of the Lakeview Reservoir project would afford a source of water supply to satisfy the immediate needs of local interests. The water supply of 291 million gallons per day from the Tennessee Colony Reservoir would serve a dual purpose - initially, 80 million gallons would be used for water quality control in the upper basin and the remaining 211 million gallons per day would be available as a source of municipal and industrial water supply for the middle basin. As the need for municipal and industrial water supply increases in the upper basin, the entire 291 million gallons per day of the Tennessee Colony water supply will be converted to serve these needs. It is anticipated that construction of the eight long-range reservoir projects in the middle basin would be phased with the gradual transfer of the Tennessee Colony water supply with construction of certain projects starting around the turn of the century so that the demands of the middle basin may continue to be fully satisfied. Initially the water supply from the Aubrey Reservoir would be used in the interest of water quality control. However, as the need for municipal and industrial water supply develops, a conversion from water quality control to water supply for municipal and industrial use would be made. There is no immediate demand for the additional water supply provided by the Roanoke Reservoir; however, it is considered that preservation of this project by acquisition of the land required at this time is desirable and economically justified. The actual project would not be constructed until the needs for the storage developed. The 13 potential projects

included in the long range plan to satisfy future requirements would be considered for authorization after detailed investigations to determine the full scope and purposes that would be justified at that time.

157. EFFECTS ON WATER QUALITY.- The water quality problem in the lower Trinity River resulting from intrusion of salt water from the Gulf will be eliminated by construction of the Wallisville Reservoir Project which has been recommended by a separate report. An element in the projects recommended herein for authorization is storage space in Tennessee Colony Reservoir and pipe line facilities from the reservoir to the existing Benbrook Reservoir for ultimate water supply. These facilities will be utilized initially for water quality control until the water supply requirements develop and local interests contract to repay the remaining costs of the facilities. The water supply storage in the Aubrey Reservoir will also be operated initially for water quality control under similar conditions. Projected water supply requirements indicate full conversion of the Aubrey Reservoir storage to water supply by about 1985, with conversion of the Tennessee Colony Reservoir and pipe line facilities to start about 2020. The facilities provided for interim use for water quality control would eliminate the septic conditions from Fort Worth to below Rosser and maintain satisfactory water quality for a considerable period in the future. It is obvious that with the projected development of the area and the conversion of interim water quality control facilities to water supply, the problems of water quality will increase. Since the water designated for interim use for quality control is provided for ultimate water supply, no provision for equivalent water quality control is required as a prerequisite for conversion to water supply. However, it is anticipated that maintenance of a satisfactory quality of water will be made possible by expected future developments in increased efficiency in treatment of water pollution.

158. EFFECT OF PLAN FOR NAVIGATION.- The recommended plan includes facilities for barge navigation from the Houston Ship Channel in Galveston Bay to Fort Worth, Texas. Through the Houston Ship Channel, connection is afforded to the Gulf Intracoastal Waterway and the extensive inland waterway system throughout the eastern and central United States. The waterway would afford low-cost water transportation to the Dallas-Fort Worth industrial complex, to the rural areas throughout the reaches of the Trinity River Basin, and the tributary trade area beyond the basin. Detailed investigation and studies show that if a waterway presently existed, large quantities of commodities consumed and produced in the basin would now move by barges, because of net savings in transportation costs. The prospective waterborne commerce is estimated at 8,800,000 tons in 1970 and 20,000,000 tons in 2020. The major commodities would be grain for export from the upper tributary trade area, sand, gravel, and stone throughout the basin and manufactured articles to and from the Dallas-Fort Worth complex. The navigation project would accommodate the prospective waterborne commerce that would develop to the year 2020, and is designed to permit expansion to provide greatly increased capacity as the prospective commerce increases to 72,000,000

tons in the year 2070. The availability of barge transportation would accelerate expansion of the industrial economy in the Dallas-Fort Worth area, especially in the reach between these two cities, where existing and proposed floodways afford extensive flood-free land for industrial plant location. The rapidly growing Houston industrial complex would take advantage of the water supply and water transportation and expand eastward into the lower Trinity. In the presently retarded middle basin the stimulus of ample water supply and flood-free conditions supplemented by low cost barge transportation would assure realization of the potential development of the natural resources and undoubtedly would result in establishment of major industrial plants.

159. FLOOD PROTECTION.- The projects recommended for authorization for flood protection are Lakeview and Tennessee Colony Reservoirs, Multiple-Purpose Channel, West Fork Floodway, Elm Fork Floodway, Dallas Floodway Extension, Duck Creek Channel Improvement, and Liberty Local Protection project. The effect of these projects would be to afford a high degree of flood protection along the Trinity River and major tributaries. These projects would provide standard project flood protection in the urban areas, greater than 100-year protection in leveed rural areas, 6 to 10 year protection in the unleveed rural areas above Tennessee Colony, and 60 to 90 year protection in the unleveed rural area below Tennessee Colony. In addition, the multiple-purpose channel would provide channel capacities consistent with a sound flood control regulation plan that would permit evacuation of flood control storage in existing and proposed reservoir projects in a period of 30 to 40 days and constitutes a fundamental and inseparable part of the reservoir system. The reduction in peak discharges of the proposed flood control improvements at various locations along the Trinity River for the floods of April-July 1942, February-May 1945, and April-July 1957 are shown in table 12. The modified discharges include the effects of all projects cited above plus the effects of the continuing program of the Soil Conservation Service. There are no flood reduction effects credited to the proposed Aubrey and Roanoke Reservoirs since the flood control impoundments in these projects are on an exchange of storage basis for additional water supply storage in the existing Garza-Little Elm and Grapevine Reservoirs.

TABLE 12

FLOOD CONTROL EFFECTS OF THE PLAN

Date of flood and location	Peak discharges (cfs) Actual	Modified by existing & authorized facilities	Proposed channel capacities	Modified by projects recommended for authorization
Flood of April-July 1942				
W. Fork Trinity R. at Fort Worth	23,700	16,400	95,000(1)	13,200
Trinity River at Dallas	111,000	53,000	226,000(2)	48,000
Trinity River at Rosser	133,000	93,000	32,000	82,300
Trinity River at Oakwood	153,000	93,500	45,000	35,000
Trinity R. at Riverside	121,000	74,700	45,000	35,000
Trinity R. at Romayor	111,000	69,600	45,000	36,500
Flood of Feb-May 1945				
W. Fork Trinity R. at Fort Worth	31,200	15,600	95,000(1)	14,900
Trinity River at Dallas	52,900	35,600	226,000(2)	26,200
Trinity River at Rosser	66,600	53,200	32,000	44,500
Trinity R. at Oakwood	140,000	123,000	45,000	35,000
Trinity R. at Riverside	116,000	103,800	45,000	36,000
Trinity R. at Romayor	106,000	93,000	45,000	38,000
Flood of April-July 1957				
W. Fork Trinity R. at Fort Worth	58,800(3)	26,800	95,000(1)	15,100
Trinity River at Dallas	222,000(3)	75,300	226,000(2)	54,000
Trinity River at Rosser	142,000(3)	56,000	32,000	29,800
Trinity R. at Oakwood	137,100(3)	81,300	45,000	27,300
Trinity R. at Riverside	130,500(3)	91,000	45,000	29,300
Trinity R. at Romayor	125,900(3)	89,000	45,000	23,500

(1) Fort Worth Floodway capacity.
(2) Dallas Floodway capacity.
(3) Estimated actual discharge without effects of existing Corps of Engineers Reservoirs.

160. OTHER PHYSICAL EFFECTS OF PLAN.- The recreational and fish and wildlife facilities proposed for development in the reservoirs and the Multiple Purpose Channel would provide recreation opportunities for a total of 25,200,000 visitors annually. Of this total visitation, about 16.4 million visitors are expected to participate in general recreation activities and 8.8 million visitors in fishing and hunting. The estimated annual visitation at existing, authorized and previously recommended Corps of Engineers reservoir projects is 22,800,000. This visitation together with the 25,200,000 annual visitation at the projects recommended in this report totals 48,000,000 which is about 60% of the recreation demand for the basin by year 2070. All of the project areas, both water-surface and dry lands, would be available to the public for recreational and fish and wildlife purposes except for the area in the Tennessee Colony Reservoir recommended as a wildlife refuge by the Bureau of Sport Fisheries and Wildlife. The Bureau proposes to manage the refuge to provide controlled public hunting and fishing at periods when these activities would not interfere with wildlife conservation management.

ECONOMIC EVALUATION OF PROJECTS RECOMMENDED FOR AUTHORIZATION

161. GENERAL.- Economic evaluations were made of projects recommended for authorization at this time. The projects were appraised to assure that: (a) project benefits exceed costs; (b) each separable unit or purpose provides benefits at least equal to its cost; (c) each element of the plan provides the maximum net benefits consistent with development of a balanced plan; and (d) there is no more economical means, evaluated on a comparable basis, of accomplishing the same purpose or purposes. The project costs and benefits were estimated on the basis of January 1962 price level.

162. COSTS.- The first costs comprise all initial expenditures for physical construction of the project, including lands and damages, relocations, reservoir clearing, engineering and design, and supervision and administration. The first costs and annual charges for all projects recommended for authorization are shown in table 13. The annual charges include interest and amortization of the investment at a Federal interest rate of 2-7/8 percent and a non-Federal interest rate of 3 percent for a 100-year period, operation and maintenance charges, and annual equivalent cost of major replacements.

163. BENEFITS.- Benefits which would accrue from the projects recommended for authorization have been estimated on the basis of a useful project life of 100 years. The benefits which are expected to accrue from future flood plain development, future use of water supplies, and future savings in transportation costs have been reduced to an average annual equivalent value by compound interest methods. The estimates of average annual benefits for the projects recommended for authorization are described below and are shown in table 13 by projects and purposes.

164. Reduction in flood damages.- The average annual benefits for flood damage reduction accruing to the various projects were determined by use of discharge-damage and discharge-frequency relations with allowances to reflect: (1) economic trends and future development in the flood plain during the period 1970 to 2070 and (2) the effects of existing, under-construction, authorized and previously recommended flood control works. On this basis the average annual damages of $15,430,000 would be reduced by the recommended projects to $1,060,000 for a benefit of $14,370,000. Additional average annual benefits in the amount of $331,000 would also accrue to the plan from the increased net return from a higher order of use of flood plain lands. The total average annual flood-control benefits resulting from the projects recommended for authorization are $14,701,000.

165. Water supply and water quality control.- Benefits for supplies of water were computed on the basis of the cost of providing the same quantity and quality of water by the cheapest alternative means. The estimated cost of the alternative means was based on non-Federal financing and interest rates for existing private and publicly owned projects. The benefits credited to the four reservoir projects which contain conservation storage (water supply and water quality control), were based on the cost of the most economical alternative single-purpose conservation facilities, including the pipeline from Tennessee Colony and amount to $8,266,000.

166. Navigation.- The multiple-purpose channel would develop navigation benefits from a savings in transportation cost of the prospective commerce between the Houston Ship Channel and Fort Worth. The survey of prospective barge commerce on the waterway indicated a total potential of about 6.9 million tons in 1958, which would increase to 22.9 million tons in 2020 and about 72.1 million tons in 2070. However, the operating capacity of the system of locks for handling vessel traffic would limit total commerce on the waterway to about 20 million tons annually. It is estimated that this volume would be reached in the year 2015 and benefits were computed on total annual commerce of 20 million tons for each year thereafter to the year 2070. Gross average annual equivalent benefits from savings in transportation costs were estimated at $27,074,000 annually for the period of analysis 1970-2070. However, increased operating costs would be incurred by vehicular traffic using the high-level fixed bridges crossing the navigation channel and a benefit would accrue to the project from the advance replacement of the reconstructed bridges. The costs to vehicular traffic were estimated and reduced to an average annual equivalent value of $323,000. The average annual equivalent benefit from advance replacement of existing bridges was estimated at $202,000. The net annual benefit from the navigation project is estimated at $26,953,000.

167. Recreation.- Benefits for general recreation were computed on the basis of estimated annual attendance at each project locality, using a unit value per visitor-day. A weighted average value of $0.50 per visitor-day was applied equally to all projects for a variety of general recreational activities including picnicking, swimming, boating, camping, sightseeing, nature study, and other outdoor pursuits. The total general recreational benefits for all projects were estimated at $6,200,000.

168. Fish and wildlife.- Benefits for fish and wildlife were computed on the basis of estimated annual attendance at each project locality using a constant unit value per visitor-day. A value of $1.00 per visitor-day was applied equally to all projects for the sports hunting and fishing afforded by the projects. Although it is recognized that the projects would have additional value as commercial fisheries and for fish and wildlife conservation purposes, a specific benefit has not been evaluated. Fish and wildlife benefits in the amount of $6,300,000 will accrue to the projects recommended for authorization.

169. ECONOMIC JUSTIFICATION.- Estimates of annual charges and benefits and ratios of benefits to costs in table 13 show that the annual benefits would exceed the annual costs for the projects considered individually and as a system.

170. Intangible benefits.- The projects recommended for authorization have been justified entirely by monetary benefits. These projects would also provide important intangible benefits in economic and social terms to the Trinity River Basin, the state of Texas, the Region and the Nation. The recommended projects would significantly increase the economic efficiency of the basin and the adjacent areas. Unemployment would be appreciably alleviated in certain areas, particularly in the middle basin of the Trinity where small areas of chronic unemployment exists. Also under utilization of resources in a large segment of the middle basin would be activated and developed, and stabilization of production and personal income and quality of work and services would be greatly improved. The flood control effects of the projects would reduce the threat to lives and stabilize the economy of the areas subject to flood and adjacent areas. Water quality control features would greatly improve the health and general welfare of the people, the recreation and fish and wildlife aspect of the projects would make an important contribution to the social well being of a large segment of the population. The water supply and navigation features of the recommended projects would directly stimulate the economy of the Trinity River Basin and large areas adjacent thereto. These intangible benefits have not been evaluated in monetary terms. However, the effect of intangible benefits were carried to the point where it was apparent that their inclusion would not make any new project eligible for recommendation for authorization. These studies were advanced, however, to the point where it was clearly evident that these intangible benefits are of major significance and would add materially to justification of the projects recommended for authorization.

TABLE 13

FIRST COST, ANNUAL CHARGES, ANNUAL BENEFITS AND BENEFIT-COST RATIOS
PROJECTS RECOMMENDED FOR AUTHORIZATION
(in thousands of dollars)

Item	Multiple-Purpose Chan. Locks and Dams	Lakeview Reservoir	Tennessee Colony Reservoir	Elm Fork Floodway	West Fork Floodway	Dallas Floodway Extension	Duck Creek Channel	Aubrey Reservoir	Roanoke Reservoir	Liberty Local Protection	Total Recommended Plan
First Cost	568.738	31,180	193.782(1)	16.823	17,809	14.327	5.024	34.073	16.900	2,091	900,747
Annual Charges	23,713	1,372	9,201(1)	723	808	605	160	1,624	624	79	38,909
Annual Benefits											
Navigation	24,002		2,951(1)	-	-	-	-	-	-	-	26,953
Flood Control	4,696	1,391	3,238	1,867	2,359	685	224	-	-	241	14,701
Water Supply and Water Quality	-	907	5,590(1)	-	-	-	-	1,085	684	-	8,266
Recreation	1,625	975	1,950	-	-	-	-	1,500(2)	150 (3)	-	6,200
Fish and Wildlife	1,750	1,050	2,100	-	-	-	-	1,400(2)	-	-	6,300
Total	32,073	4,323	15,829	1,867	2,359	685	224	3,985	834	241	62,420
Benefit-Cost Ratio	1.4	3.2	1.7	2.6	2.9	1.1	1.4	2.5	1.3	3.0	1.6

(1) Includes costs and benefits for pipeline and navigation.
(2) Includes increased benefits at the Garza-Little Elm reservoir project.
(3) Includes increased benefits at the Grapevine reservoir project.

COST ALLOCATION AND APPORTIONMENT

171. COST ALLOCATION TO PROJECT PURPOSES.- Cost allocations for multiple-purpose projects were made to determine the equitable distribution of the costs to each project purpose. All reservoir project costs were allocated by the separable costs-remaining benefits method using an amortization period of 100 years and an interest rate of 2-7/8 percent. Project costs for Aubrey and Roanoke Reservoirs were not considered allocable to flood control but rather to water supply and recreation - fish and wildlife since an exchange of equivalent storage for flood control was made between Aubrey and Garza-Little Elm and Roanoke and Grapevine projects. Allocation of total costs of Aubrey and Roanoke Reservoirs, including modifications and additions of recreation and fish and wildlife facilities in Garza-Little Elm and Grapevine, were made by the separable costs-remaining benefits method for the purposes of water supply and recreation - fish and wildlife. The costs allocated in this manner for the four reservoir projects are summarized in table 14. Although the Multiple Purpose Channel was formulated by the incremental method, a cost allocation between purposes was made by allocating all specific costs to purposes served with the remaining joint costs distributed to flood control and navigation purposes on a fair share basis in proportion to their benefits. Only specific costs were allocated to recreation - fish and wildlife features of the multiple-purpose channel. Since the local protection projects were solely for flood control, no cost allocation was necessary. Figure 29 graphically shows the distribution to project purposes of the total cost of all of the projects recommended for authorization in this report.

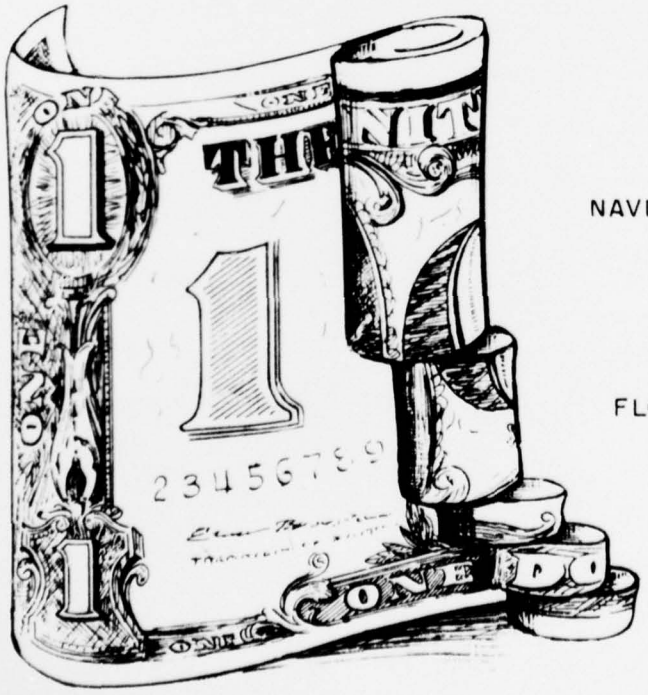


FIGURE 29

COSTS ALLOCATED TO PURPOSES

TABLE 14

ALLOCATION OF COSTS

Project & Purpose	First Cost	Annual Charges	Annual Benefits	B/C Ratio
	$	$	$	
Lakeview Reservoir:				
Flood control	9,213,700	358,100	1,391,000	3.9
Water supply	14,960,200	566,300	907,300	1.6
Recreation - fish & wildlife	7,006,100	447,600	2,025,000	4.5
Total	31,180,000	1,372,000	4,323,300	3.2
Aubrey Reservoir: (1)				
Water supply	22,951,600	826,550	1,085,200	1.3
Municipal & industrial	(14,360,800)	(517,150)	(679,000)	(1.3)
Quality control	(8,590,800)	(309,400)	(406,200)	(1.3)
Recreation - fish & wildlife	11,121,400	797,850	2,900,000	3.6
Total	34,073,000	1,624,400	3,985,200	2.5
Roanoke Reservoir: (2)				
Water supply	14,997,100	526,100	683,700	1.3
Recreation	1,902,900	97,700	150,000	1.5
Total	16,900,000	623,800	833,700	1.3
Tennessee Colony Reservoir:				
Flood control	42,663,600	1,492,800	3,238,000	2.2
Water supply	84,277,300	4,192,900	5,589,600	1.3
Municipal & industrial	(29,679,200)	(1,262,300)	(1,975,400)	(1.6)
Quality control	(54,598,100)	(2,930,600)	(3,614,200)	(1.2)
Navigation	51,893,000	2,427,600	2,951,000	1.2
Recreation - fish & wildlife	14,948,100	1,088,100	4,050,000	3.7
Total	193,782,000	9,201,400	15,828,600	1.7

(1) Includes costs and benefits of the modification of Garza-Little Elm project.
(2) Includes costs and benefits of the modification of Grapevine project.

172. APPORTIONMENT OF COSTS AMONG INTERESTS.- The apportionment between Federal and non-Federal interests of construction costs and annual operation, maintenance, and replacement costs is shown in table 15. Existing laws, policies, and procedures for apportionment of costs of public works among the various users, interests, and agencies that will contribute to the cost of the project differ with project purposes, types of development, and beneficiaries. The apportionment of costs is discussed in the following paragraphs.

173. Flood control.- Costs allocated to flood control are apportioned between Federal and non-Federal interests in accordance with the general policy given in the Flood Control Act of 1936 (Public Law 738, 74th Congress), as subsequently amended. All costs allocated to flood control features of the reservoirs and multiple-purpose channel are apportioned to the Federal Government because of the widespread and general benefits associated with the flood control effects of these projects and because the channel is a necessary and inseparable adjunct to the reservoirs for efficient and effective flood-control regulation. Costs for the local flood protection projects are assigned to the Federal Government except for the costs of lands, easements, rights-of-way and relocations (excluding railroads) and the annual operation, maintenance, and replacement costs, all of which are the responsibility of local interests.

174. Navigation.- Costs allocated to navigation are apportioned between Federal and non-Federal interests in accordance with Congressional policies expressed in legislation applicable to projects for general navigation. The Federal Government will bear the construction costs associated with navigation in the multiple-purpose channel, including navigation locks and dams and construction of bridges in new land cuts. The costs of bridge alterations over existing channels will be apportioned between Federal and non-Federal interests in accordance with the principles of Section 6 of the Bridge Alteration Act (Truman-Hobbs) of June 21, 1940, as amended. Non-Federal interests will bear a fair share of the costs of all lands, easements, rights-of-way and relocations (except bridges) for the multiple-purpose channel allocated in proportion to the benefits credited to the various purposes. The costs of maintenance dredging of the channel and operation and maintenance of the locks and dams will be borne by the Federal Government. The costs of operation and maintenance of all bridges are the responsibility of non-Federal interests.

175. Water supply and water quality control.- Costs allocated to storage for water quality control have been apportioned to the Federal Government, in accordance with the Water Pollution Control Act of 1948, as amended. All costs allocated to water supply for municipal and industrial uses are the responsibility of non-Federal interests, in accordance with the provisions of the Water Supply Act of 1958, (Public Law 500, 85th Congress), as amended. The provision for water supply

includes both that needed for immediate use (present demand storage) and for future use (future demand storage). Payment of first costs allocated to present demand storage will be made by non-Federal interests starting at the time water is available for delivery and payment of costs incurred for future demand storage need not be made by non-Federal interests until use is initiated. No interest will be charged on the investment costs for future water supply until use is initiated, but such interest-free period shall not exceed ten years. Operation and maintenance costs associated with the water supply for municipal and industrial uses are apportioned to local interests.

176. Recreation-fish and wildlife.- Recreation-fish and wildlife encompasses both general recreation and fish and wildlife recreation, which are considered to be project purposes of the recommended projects and which is in consonance with Senate Document 97, 87th Congress, 2d Session. Costs allocated to recreation-fish and wildlife are recommended as a Federal cost since the allocated costs for recreation-fish and wildlife for each project in the recommended plan fall within the criteria established by the Chief of Engineers that Federal costs include all specific costs plus joint costs not to exceed 25 percent of the total project cost.

TABLE 15

APPORTIONMENT OF COSTS

Project	First Cost			Operation, Maintenance & Replacement Costs		
	Federal	Non-Federal	Total	Federal	Non-Federal	Total
	$	$	$	$	$	$
Multiple-Purpose Channel	537,029,000	31,709,000	568,738,000	3,863,000	290,000	4,153,000
Reservoirs:						
Lakeview	16,220,000	14,960,000	31,180,000	275,000	77,000	352,000
Aubrey (1)	19,712,000	14,361,000	34,073,000	462,000	47,000	509,000
Roanoke (2)	1,903,000	14,997,000	16,900,000	36,000	42,000	78,000
Tennessee Colony	164,103,000	29,679,000	193,782,000	2,521,000	281,000	2,802,000
Local Protection:						
West Fork (3)	10,719,000	7,090,000	17,809,000	-	224,000	224,000
Elm Fork	11,191,000	5,632,000	16,823,000	70,000	103,000	173,000
Dallas Floodway Extension (3)	8,949,000	5,378,000	14,327,000	-	135,000	135,000
Duck Creek	4,176,000	848,000	5,024,000	-	6,000	6,000
Liberty Levee (3)	1,794,000	297,000	2,091,000	-	15,000	15,000
Total	$775,796,000	$124,951,000	$900,747,000	$7,227,000	$1,220,000	$8,447,000

(1) Including modification of Garza-Little Elm Reservoir.
(2) Including modification of Grapevine Reservoir.
(3) Exclusive of multiple-purpose channel.

LOCAL COOPERATION

177. PROPOSED LOCAL COOPERATION.- The projects recommended for authorization for the Trinity River Basin include a multiple-purpose channel, four multiple-purpose reservoirs, and five local flood protection projects. The proposed requirements of local cooperation are discussed in the subsequent paragraphs.

178. Multiple-Purpose Channel.- The proposed requirements of local cooperation for the Multiple-Purpose Channel are as follows:

a. Provide the share apportioned to navigation of the actual cost to the United States for all lands, easements, and rights-of-way, required for construction and subsequent maintenance of the project and for aids to navigation upon request of the Chief of Engineers, including suitable areas determined by the Chief of Engineers to be required in the general public interest for initial and subsequent disposal of spoil;

b. Hold and save the United States free from damages due to construction of works for navigation and from damages to real estate (land and improvements) resulting from dredging, changes in ground water level and wave action caused by operation and maintenance of the project;

c. Provide a proportionate share of the cost of bridge alterations over existing channels in accordance with the principles of Sec. 6 of the Bridge Alteration Act (Truman-Hobbs) of June 21, 1940, as amended;

d. Assume all obligations, owning, maintaining and operating all railway and highway bridges altered or constructed as part of the multiple-purpose channel project, with such obligation for each bridge to be assumed by local interests upon final completion of alteration or construction of that bridge;

e. Provide and maintain at local expense adequate public terminal and transfer facilities open to all on equal terms; provide and maintain without cost to the United States depths in berthing areas and local access channels serving the navigation channel commensurate with the depths provided in the related areas;

f. Provide the share apportioned to navigation of the actual cost to the United States for alterations of sewer, water supply, drainage, pipeline, and other utility facilities;

g. Obtain without cost to the United States any water rights that may be found necessary for operation of the project in the interest of navigation; and

h. Provide a cash contribution of 5.58 percent of the actual Federal cost of construction which includes items (a), (c), and (f) above. The cash contribution apportioned to local interests is currently estimated at $31,709,000.

179. Reservoirs.- The proposed requirements of local cooperation for the multiple-purpose reservoirs are as follows:

a. Provide the share of the cost of the reservoirs allocated to municipal and industrial water supply in accordance with the provisions of the 1958 Water Supply Act, as amended. These costs for each reservoir are currently estimated as follows:

Reservoir	Cost (in thousands of dollars) Construction	Annual O&M
Lakeview	14,960	77
Roanoke-Grapevine	14,997	42
Aubrey-Garza-Little Elm (1)	14,361	47
Tennessee Colony (1)	29,679	281

(1) Excludes cost allocated to water quality control during interim use.

b. Obtain without cost to the United States all water rights necessary for operation of the project in the interest of water supply.

180. Local flood protection projects.- The projects recommended for authorization also include as local flood protection projects the West Fork Floodway; Elm Fork Floodway; Dallas Floodway Extension; Liberty Local Protection Project; and Duck Creek channel. The requirements of local cooperation for participation in these works of improvement except for the channel portion of the West Fork Floodway, Elm Fork Floodway, and Dallas Floodway Extension projects are as follows:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction, maintenance and operation of the projects;

b. Provide without cost to the United States all relocations of buildings and utilities, bridges (except railroad), sewers, pipelines, and any other alterations of existing improvements which may be required for the construction of the project;

c. Provide assurances that encroachment on improved channels and floodways or ponding areas will not be permitted, and that, if ponding areas and capacities are impaired, substitute storage capacity or equivalent pumping capacity will be provided promptly without cost to the United States;

d. Hold and save the United States free from damages due to the construction works;

e. Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army;

f. Agree to publicize flood plain information in the community and area concerned and to provide this information to zoning and other regulatory agencies and public information media for their guidance and appropriate action.

181. LOCAL COOPERATION OFFERED.- The President of the Trinity Improvement Association and Chairman of the Executive Committee of the Trinity River Authority of Texas by letters dated October 2,1961 and August 9, 1962, and informal discussion, has stated that it is the intent of these organizations to sponsor the projects recommended for authorization in this report and to undertake to comply singularly or jointly on items of cooperation required of local interests.

COORDINATION WITH OTHER AGENCIES

182. INITIATION OF STUDIES.- The study on the Trinity River Basin was initiated during the fall of 1957. The regional offices of other interested Federal agencies and the State of Texas were advised of this action by letter dated November 20, 1957. In response to the letter, the Federal agencies, in general, indicated an interest in the study, offered information on available basic and general data, and requested that copies of the report be submitted for field-level review and comment.

183. U. S. PUBLIC HEALTH SERVICE.- Estimates of the water supply needs and values for various purposes have been coordinated with the Public Health Service. On the basis of this coordination, the Public Health Service prepared a report presenting its determinations of the value of additional water supply that would result from construction of the Lakeview, Tennessee Colony, Roanoke, and Aubrey Reservoirs; results of water quality studies; problems concerning, and need for, pollution abatement; and water requirements for years 2020 and 2070. This report has been included as a part of Appendix II.

184. BUREAU OF SPORT FISHERIES AND WILDLIFE.- The Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, was consulted regarding the fish and wildlife aspects of the recommended plan of development. The Bureau, in cooperation with the Bureau of Commercial Fisheries and the Texas Game and Fish Commission, prepared a report on the fish and wildlife aspects of the Lakeview and Tennessee Colony Reservoirs and the multiple-purpose channel. In accordance with the recommendations made in the report by the Bureau of Sport Fisheries and Wildlife, provisions have been incorporated in the plan for the Tennessee Colony Reservoir for development of a wildlife refuge. This agency report has been included as part of Appendix V.

185. NATIONAL PARK SERVICE.- The National Park Service, Department of the Interior, was requested to evaluate the recreational aspects and potentialities of the recommended Lakeview and Tennessee Colony Reservoirs and the multiple-purpose channel. A representative of the National Park Service prepared a report which contained an appraisal of the recreational potential and estimated monetary evaluation of the recreational benefits, which has been included as a part of Appendix V.

186. U. S. BUREAU OF RECLAMATION.- The Bureau of Reclamation, Department of the Interior, was consulted during the progress of the report studies to determine if there was a need and justification for the inclusion of irrigation storage space as a Federal purpose in any of the recommended reservoir projects in the Trinity River Basin.

Studies by the Bureau revealed that lands suited for irrigation can best be developed by individual land owners rather than by project-type facilities. Therefore, the reservoir projects recommended for authorization do not provide any storage space specifically allocated for irrigation purposes. The Bureau also has underway an investigation entitled, "Texas Basin Project," dealing with the water resources of the Texas streams that flow into the Gulf of Mexico. In this connection, consideration is being given to a system of canals, natural channels and appurtenant control structures to serve as a system for conveyance of water southwesterly along the Gulf Coast to water deficient areas. A storage reservoir on the lower Trinity River is indicated as a part of the Bureau plan. An analysis of the projected water requirements for the Trinity River Basin and of measures recommended to satisfy these requirements, as developed in this report, discloses that water for that purpose would not be available for export from the basin.

187. U. S. SOIL CONSERVATION SERVICE.- During investigation for this report and the report prepared for the U. S. Study Commission - Texas, numerous conferences were held which involved members of the Fort Worth and Galveston Districts and members of the Soil Conservation Service. Many problems associated with hydrology, hydraulics, economics, drainage, design, integrated river basin planning, and other related items were discussed. Engineering data made available as a result of these conferences generally served as the basis for an integrated and complementary plan of water resources development for the Trinity River Basin.

188. FEDERAL POWER COMMISSION.- The Fort Worth regional office of the Federal Power Commission was requested to prepare estimates of power and energy values for the potential development of hydroelectric power at the Lakeview and Tennessee Colony Reservoir projects, based on January 1962 price levels. These values were used in studies to determine the economic justification for including hydroelectric power as a specific purpose in these projects.

189. BUREAU OF PUBLIC ROADS AND TEXAS HIGHWAY DEPARTMENT.- The Bureau of Public Roads and the Texas Highway Department were contacted during the progress of the study so that the future plans of these agencies may be fully integrated into the overall comprehensive plan of development. All highway relocations and related activities in the plan of development have been accomplished generally in accordance with the policies and procedures of the Bureau of Public Roads and the Texas Highway Department.

190. TEXAS WATER COMMISSION - During the investigation for this report and the report prepared for the U. S. Study Commission - Texas, many conferences and informal discussions were held with various representatives of the Texas Water Commission. Basic data, agency procedures, project formulation, coordination of the Corps of Engineers' plan with

that developed by the Commission and the Trinity River Authority, and many other engineering and policy matters were discussed. Engineering data compiled and reports published by the Commission were used in connection with the basin studies.

191. U. S. STUDY COMMISSION - TEXAS.- In the process of developing the report of the U. S. Study Commission - Texas separate plans for each of the eight basins were prepared for incorporation into an integrated overall plan for the entire area. The Corps of Engineers was assigned the formulation of preliminary plans for four of the basins including the Trinity River. In the development of these plans for the Commission certain basic hydrologic, economic, and other data were computed by the U. S. Bureau of Reclamation, Soil Conservation Service, other Federal agencies, and State agencies. Much of the data prepared for the U. S. Study Commission - Texas has been used by the Corps of Engineers in the development of the comprehensive plan for the Trinity River Basin. The proposed Trinity River Basin plan is in full consonance with the U. S. Study Commission - Texas plan.

192. REVIEW OF REPORT BY OTHER AGENCIES.- Copies of this report have been forwarded to the interested Federal agencies at field level and the Texas Water Commission for their preliminary views and comments. Letters from these agencies containing their comments and replies where appropriate are presented in Appendix VIII of this report. The comments are summarized briefly in the following subparagraphs.

a. U. S. Public Health Service.- The Public Health Service, by letter dated August 9, 1962, stated that minor inconsistencies between data contained in the Corps report and their report which is included as Exhibit 1, Appendix II, had been resolved and offered no further comment.

b. Bureau of Sport Fisheries and Wildlife.- The comments of the Corps of Engineers on the recommendations contained in the Bureau of Sport Fisheries and Wildlife report are contained in Appendix V. The Bureau of Sport Fisheries and Wildlife, by letter dated August 3, 1962, expressed their disappointment with our decision that the proposal for a national wildlife refuge should be considered separately from the reservoir project. Studies have shown that the refuge as proposed by the Bureau of Sport Fisheries and Wildlife is a separable economic component which could be included or excluded from the overall development without affecting the justification of the other purposes of the reservoir and it was concluded that the Fish and Wildlife Service and the Department of the Interior would be the agencies responsible for providing necessary detail and specific technical support for the refuge, as may be necessary. The Bureau of Sport Fisheries and Wildlife stated that they stand ready to support the proposal before Congress or at such times and places as are appropriate. The Bureau also noted a wide variance between the fish and wildlife benefits estimated by them and the Corps of Engineers. The Corps estimates of benefits are based on experienced visitor use at comparable operating Corps reservoirs throughout the area and are considered conservative. In developing the estimates, consideration was

given to present population density, predicated population increases during project life, and competition to be satisfied from existing and other proposed reservoirs.

c. National Park Service.- The National Park Service, by letter dated August 3, 1962, stated that they had reviewed the report and had no comment.

d. U. S. Bureau of Reclamation.- The Bureau of Reclamation, by letter dated August 17, 1962, stated that the report is of interest in connection with their Texas Basin Project Study and that they had no comments to offer at field level.

e. U. S. Soil Conservation Service.- By letter dated August 13, 1962, the Soil Conservation Service proposed certain comments and revisions which have been included in the report. The Soil Conservation Service stated that with consideration of their comments, they felt that the treatment of agricultural phases and recognition of Soil Conservation Service programs, together with coordination of activities of our respective agencies, was presented adequately in the report.

f. Federal Power Commission.- The Federal Power Commission by letter dated August 16, 1962, expressed their opinion that facilities for generation of power should not be recommended at this time at any of the projects proposed. However, they further stated that power potentialities in the Tennessee Colony Project should be restudied during preconstruction planning.

g. Bureau of Public Roads.- The Bureau of Public Roads in their letter dated July 30, 1962, stated that the basic regulations of the Bureau will not permit the use of Federal-aid highway funds to relieve local interests of their obligations concerning highway and bridge relocations and alterations incurred as a result of construction of the recommended projects.

h. Bureau of Mines.- The comments by the Bureau of Mines in their letter dated August 20, 1962, were that it does not object to Federal authorization for the recommended projects provided that mineral resources and mineral producing and handling facilities are protected for continued operation and development.

i. U. S. Geological Survey.- The U. S. Geological Survey, by letter dated August 29, 1962, stated that the comprehensive report anticipates major future water use and water control needs and offered no objection to the projects proposed in the report.

j. Southwestern Power Administration.- By letter dated August 29, 1962, the Southwestern Power Administration stated that a

review of the pertinent portions of the report indicate that the interests of the Administration would not be affected by the proposed improvements.

k. Texas Water Commission.- The Commission furnished comments on the draft of the report and two conferences were held with staff personnel of the Commission and the Corps of Engineers to consider various aspects of the report. Subsequent revisions have been made in the report as a result of these considerations. In their letter of September 11, 1962, the Commission concluded to withhold its formal comments pending the public hearing to be held in accordance with Article 7472e, Vernon's Civil Statutes of Texas.

DISCUSSION AND CONCLUSIONS

193. DISCUSSION.- The economic situation in the Trinity River Basin can be described as a vigorous, expanding business and industrial complex in the upper portion of the basin and in the area along the Gulf coast that compares favorable with other urbanized areas of equal size in the United States. In the remaining portions of the basin the opposite exists with the generally agricultural economy either stationary or declining. The areas of vigorous growth are expected to continue to grow. The remaining areas have a vast potential for economic growth that requires only the control of frequent long duration floods, the provision of regulated water supplies, and a water transportation system.

194. The comprehensive plan of development for the water and related land resources of the Trinity River Basin gives full recognition of the needs that must be satisfied to provide unimpeded development in the upper basin and coastal area and to stimulate the great economic development that is possible in the middle and lower basins. Basic in any planning is the scheduling of projects for orderly development of an area, and it became evident early in the studies that a flood control channel was required now as a basic part of the established flood control program of reservoirs and floodways, as well as for any new flood control projects. It also became apparent that modification of this channel to provide water navigation was practical and vital to the economic development of the basin and the region. In addition to the multiple-purpose channel, immediate needs and justification were found for the development of additional facilities for flood control, water supply, water quality control, recreation and fish and wildlife. This led to the development of the projects recommended for authorization, all of which are integral parts of the comprehensive plan and are economically justified individually and as a system. The magnitude of the resources of the Trinity River Basin in relation to the immediate and long-range needs of the area was not conducive to alternative plans of in-basin development if maximum practical satisfaction of all of the needs were to be met.

195. The projected water supply to satisfy the needs by the year 2070 for municipal and industrial use, non-municipal use, water quality control, navigation, irrigation, and including exportation to the City of Houston would require the full development of the water resources of the basin. The plan for development of the water resources was formulated to operate within the framework of permits issued by the Texas Water Commission to local interests and permit 1970 granted jointly to the City of Houston and the Trinity River Authority. Studies showed that additional supplies from surface water resources obtained by the development of the four reservoirs recommended for authorization in this report and the phased development of the thirteen long-range reservoir projects together with the maximum practical development of

ground water, and the use of return flow would be required to satisfy fully the projected water supply needs of the basin by 2070. Studies also revealed that the Tennessee Colony and Aubrey Reservoirs could be scheduled for construction, so that interim use of the water supply could be made to satisfy immediate and near future water quality requirements to eliminate the septic conditions in the Trinity River from Fort Worth to below Rosser. Accordingly, pipe line facilities from the Tennessee Colony Reservoir to the existing Benbrook Reservoir were provided and a yield of 80 million gallons of water per day from Tennessee Colony and 40 million gallons of water per day from Aubrey Reservoir would be utilized initially for water quality control. The pipe line facilities and reservoir storage used for water quality control would be converted to fulfill municipal and industrial water needs as they develop and local interests contract to repay the remaining costs of the facilities. The facilities utilized on an interim basis for water quality control are provided to satisfy ultimate water supply requirements and conversion to this purpose places no obligation on those contracting for the facilities to provide replacement water quality control measures. Prior to construction of Aubrey Reservoir (including modification of Garza-Little Elm), arrangements for operation and future conversion of these projects would be made with the cities of Dallas and Denton which have contracts with the United States for existing conservation storage in Garza-Little Elm Reservoir and hold permits from the State of Texas for the water use. With respect to water quality it is anticipated that as conversion is made to water supply the maintenance of a good quality of water will be made possible by expected future developments in increased efficiency in treatment of water pollution.

196. In the formulation of the plan for meeting the water supply demands in the basin, it was recognized that the people who will ultimately require additional water resources may prefer to import water rather than to develop in-basin resources such as ground water and return flow. In such a situation the available water resources within the basin may not be fully utilized. Importation of water from other areas would not alter the need for or the economic justification of the projects recommended for authorization in this report. As the needs arise in the future, studies can be made to determine the best solution of the several alternatives then existing.

197. The navigation features of the multiple-purpose channel were designed to accommodate efficiently the size and type of equipment expected to carry the prospective commerce on the waterway during the immediately foreseeable future. The water requirements necessary to operate the navigation facilities would be satisfied by return flows and existing navigation storage and no additional storage is required for this purpose. On the basis of the projected increases in commerce and on the expected pattern of distribution of the commodities and movements of tows, it was found that the capacity

of the locks in the reach immediately below Dallas would be reached by the expected traffic in the year 2015. Considerable increase in the carrying capacity of the waterway, however, could be realized by rearrangement of tows being locked through the restrictive locks and by some restriction on movement of pleasure craft. The waterway navigation facilities were found to be economically justified at this time on the basis of reaching a maximum capacity through the year 2020. Further increase in capacity could be obtained by construction of additional locks and eventually by widening of the channel. Since the initial development was found to be economically justified as a unit and on the basis of the projections of commerce, enlargement would not be needed until 2020, there is no justification in the public interest for constructing a larger waterway at this time. However, the plan recommended herein is designed so that enlargement of the waterway to accommodate the projected commerce can be provided as the need arises and the cost of the added works is found justified.

198. The pattern of economic growth in the area of the Roanoke Reservoir indicates that extensive development can be expected to take place before the project will be required for water supply. Such development, if not limited, could preclude the construction of the reservoir because of high cost of lands, relocations and damages. It was found desirable and economically justified to obtain an interest in the necessary lands in advance of construction so as to preserve the dam site and reservoir from encroachment. A minimum interest in the lands consistent with the objective of site and reservoir preservation would be obtained. Prior to construction, tenancy would be preserved where practical with development for recreation and fish and wildlife on areas where outright purchase was necessary. Measures are also provided for advance participation in construction or reconstruction of transportation facilities to minimize costs for relocations.

199. Construction of the multiple-purpose channel recommended for authorization in this report would likely extend over a number of years in the future. In the interim, construction of Livingston Reservoir by the City of Houston is scheduled to be initiated in the immediate future. Construction of that reservoir will require relocation of transportation and utility lines which would have to be subsequently further modified when the multiple-purpose channel is constructed. If the Federal Government were to participate in such relocations, significant saving in cost to the United States would be realized. The savings in public funds as well as the avoidance of added inconvenience to transportation traffic occasioned by separate relocations, would warrant the expenditure of Federal funds in advance of start of overall construction of the multiple-purpose channel. Measures are recommended herein for advance participation in relocations on Livingston Reservoir to avoid increased costs.

200. Economic growth will continue along the proposed alignment of the multiple-purpose channel and adjacent to the local protection projects in advance of construction. Rapid acceleration and expansion

of transportation and utility facilities normally accompany a growing economy. The time-sequence of the expanding transportation and utility work should, insofar as practicable, be phased with the design and construction of the proposed waterway and local protection works. Every effort should be made to advance design and construction of the works proposed herein in phase with transportation and utility relocations to effect savings in public funds and to minimize adverse effects on the orderly development of the basin. If the recommended projects are authorized, participation by the United States in such undertakings should be coordinated with local interests on an individual basis with the view to submitting to Congress separate reports on desirable participation.

201. The needs for flood control, navigation, and water quality control are immediate and it is anticipated that projects involving these purposes would be initiated soon after authorization. In scheduling the accomplishment of individual units of the program, consideration would be given to the requirements for all purposes, with particular attention given to provision of water supply storage in order to meet the projected needs as they develop. Since construction by the Corps of Engineers is determined by appropriation of funds by Congress no assurance can be given herein that Federal construction would be undertaken in accordance with a particular schedule. Under these circumstances, it should not be construed that Federal authorization would constitute a preemption of a site or would prohibit development of a site by local interests if water supply needs develop in advance of Federal appropriations for a project.

202. Additional information on recommended projects called for by Senate Resolution 148, Eighty-fifth Congress, adopted January 28, 1958, is contained in an attachment to this report. (Appendix I)

203. CONCLUSIONS.- The comprehensive basin plan provides for the development of the water and related land resources to meet the immediate and long range needs. The projects recommended for authorization and immediate construction are those found necessary for the orderly development of the water and related land resources consistent with the present and projected economic conditions of the Trinity River Basin. The projects are consistent with the comprehensive plan for basin development and are multiple purpose in scope. They are well justified both individually and as a system and each purpose served by the projects is fully justified. Projects recommended for inclusion in the long range plan but not recommended for authorization at this time would only be considered for Federal participation after detailed studies are made to develop the full comprehensive requirements of each project and its justification. The comprehensive basin plan including the projects recommended for authorization and immediate construction is in full consonance with the recommendations of the U. S. Study Commission - Texas which contemplates that their plan be followed as a flexible framework guide in detailed planning for subsequent survey reports for project authorization by appropriate Federal agencies.

RECOMMENDATIONS

204. RECOMMENDATIONS.- On the basis of the studies and conclusions made for this report, it is recommended that the comprehensive plan be recognized as the plan for the full development and beneficial public use of the water and related land resources of the Trinity River Basin and that the existing, under construction, authorized, and previously recommended projects for the Trinity River Basin be supplemented to provide:

a. A multiple-purpose channel extending along the Trinity River from the Houston Ship Channel to Fort Worth, Texas, including enlargement of the navigation lock previously recommended for construction in connection with the Wallisville Reservoir and spur channels and turning basins in Dallas and Fort Worth.

b. Multiple-purpose reservoirs:

(1) Lakeview Reservoir
(2) Roanoke Reservoir (including modification of Grapevine Reservoir)
(3) Aubrey Reservoir (including modification of Garza-Little Elm Reservoir)
(4) Tennessee Colony Reservoir

c. Local flood protection projects:

(1) West Fork Floodway
(2) Elm Fork Floodway
(3) Dallas Floodway Extension
(4) Duck Creek Channel Improvement
(5) Liberty Local Protection Project

d. That the foregoing be accomplished with such changes and modifications as in the discretion of the Chief of Engineers may be advisable, at an estimated total construction cost of $900,747,000 and $8,447,000 annually for maintenance and operation. The net cost to the Federal Government for construction and the annual maintenance and operation cost are estimated at $775,796,000 and $7,227,000, respectively.

e. That the Chief of Engineers be authorized to acquire an interest in the reservoir and dam site lands and to participate in construction or reconstruction of transportation and utility facilities for the Roanoke Project in advance of construction as required to preserve such areas from encroachment and to avoid increased costs for relocations. The interest in lands to be acquired would be the minimum necessary consistent with the objective of reservoir and dam site preservation. This authorization would enable the Chief of Engineers to cooperate with

responsible local interests to keep lands on local tax rolls and to exercise control over development in the reservoir and dam site area until needed for project purposes.

f. That the Chief of Engineers be authorized to participate in relocations in the Livingston Reservoir in advance of the start of actual construction on the multiple-purpose channel project, when relocation of existing or construction of new highways, railroads, pipelines, and utility lines that would subsequently have to be modified for project purposes, are undertaken by other agencies; provided that a net saving in cost of construction to the United States will result; and provided further that funds shall be expended only on those relocations required for project purposes.

g. That, prior to initiation of construction, responsible local interests give assurances satisfactory to the Secretary of the Army that they will:

(1) With respect to the multiple-purpose channel:

(a) Provide the share apportioned to navigation of the actual Federal cost for all lands, easements, and rights-of-way required for construction and subsequent maintenance of the project and for aids to navigation upon the request of the Chief of Engineers, including suitable areas determined by the Chief of Engineers to be required in the general public interest for initial and subsequent disposal of spoil;

(b) Hold and save the United States free from damages due to construction of navigation works and from damages to real estate (land and improvements) resulting from dredging, changes in ground water level and wave action caused by operation and maintenance of the project;

(c) Provide a proportionate share of the cost of bridge alterations over existing channels in accordance with the principles of Section 6 of the Bridge Alteration Act (Truman-Hobbs) of June 21, 1940, as amended;

(d) Assume all obligations, owning, maintaining and operating all railway and highway bridges altered or constructed as part of the multiple-purpose channel project, with such obligation for each bridge to be assumed by local interests upon final completion of alteration on construction of that bridge;

(e) Provide and maintain at local expense adequate public terminal and transfer facilities open to all on equal terms; provide and maintain without cost to the United States depths in berthing areas and local access channels serving the navigation channel commensurate with the depths provided in the related areas;

(f) Provide the share apportioned to navigation of the actual Federal cost for alterations of sewer, water supply, drainage, pipelines, and other utility facilities;

(g) Obtain without cost to the United States any water rights that may be found necessary for operation of the project for navigation;

(h) Provide a cash contribution of 5.58 percent of the actual Federal cost of construction which includes items (a), (c), and (f) above. The cash contribution is presently estimated at $31,709,000.

(2) With respect to Lakeview, Roanoke, Aubrey and Tennessee Colony Reservoirs:

(a) Reimburse the United States for the water supply storage in the project on terms which will permit paying out the costs allocated thereto as determined by the Chief of Engineers, in accordance with the provisions of the Water Supply Act of 1958, as amended; such costs presently estimated as shown below:

Reservoir	Allocated costs to water supply			
	Construction costs		Annual O&M costs	
	Amount (dollars)	Percent	Amount (dollars)	Percent
Lakeview	14,960,000	47.98	77,000	21.81
Roanoke	14,997,000	88.74	42,000	53.53
Aubrey	14,361,000	42.15	47,000	9.25
Tennessee Colony	29,679,000	15.32	281,000	10.04

with such modification in these amounts as may be necessary to reflect adjustments in the storage capacity for water supply and other purposes, except that these costs and percentages may be revised in the preconstruction planning stage; and

(b) Obtain without cost to the United States all water rights necessary for operation of the project in the interest of water supply.

(3) With respect to West Fork Floodway, Elm Fork Floodway, Dallas Floodway Extension (except for the channel portions thereof),

Duck Creek Channel Improvement, and Liberty Local Protection Project:

(a) Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction, maintenance and operation of the project;

(b) Provide without cost to the United States all relocations of buildings and utilities, bridges (except railroads), sewers, pipelines, and any other alterations of existing improvements which may be required for the construction of the project;

(c) Provide assurances that encroachment on improved channels and floodways or ponding areas will not be permitted; and that, if ponding areas and capacities are impaired, substitute storage capacity or equivalent pumping capacity will be provided promptly without cost to the United States;

(d) Hold and save the United States free from damages due to the construction works;

(e) Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army;

(f) Agree to publicize flood plain information in the community and area concerned and to provide this information to zoning and other regulatory agencies and public information media for their guidance and appropriate action.

205. It is also recommended that, in the interest of comprehensive planning and development of the water resources of the Trinity River Basin, the Congress give careful consideration to the recommendations of the Bureau of Sport Fisheries and Wildlife providing for fee acquisition of about 600 acres of land immediately adjacent to the Tennessee Colony Reservoir at an estimated additional cost of $145,000, and should the acquisition of the additional lands be authorized, the Corps of Engineers be also authorized to make available to the Secretary of the Interior for a national wildlife refuge, about 20,400 acres of land within the Tennessee Colony Reservoir and authorize the Chief of Engineers to operate the Tennessee Colony Reservoir in support of the Wildlife refuge insofar as it does not conflict or interfere with the operations for other project purposes.

James S. Maxwell

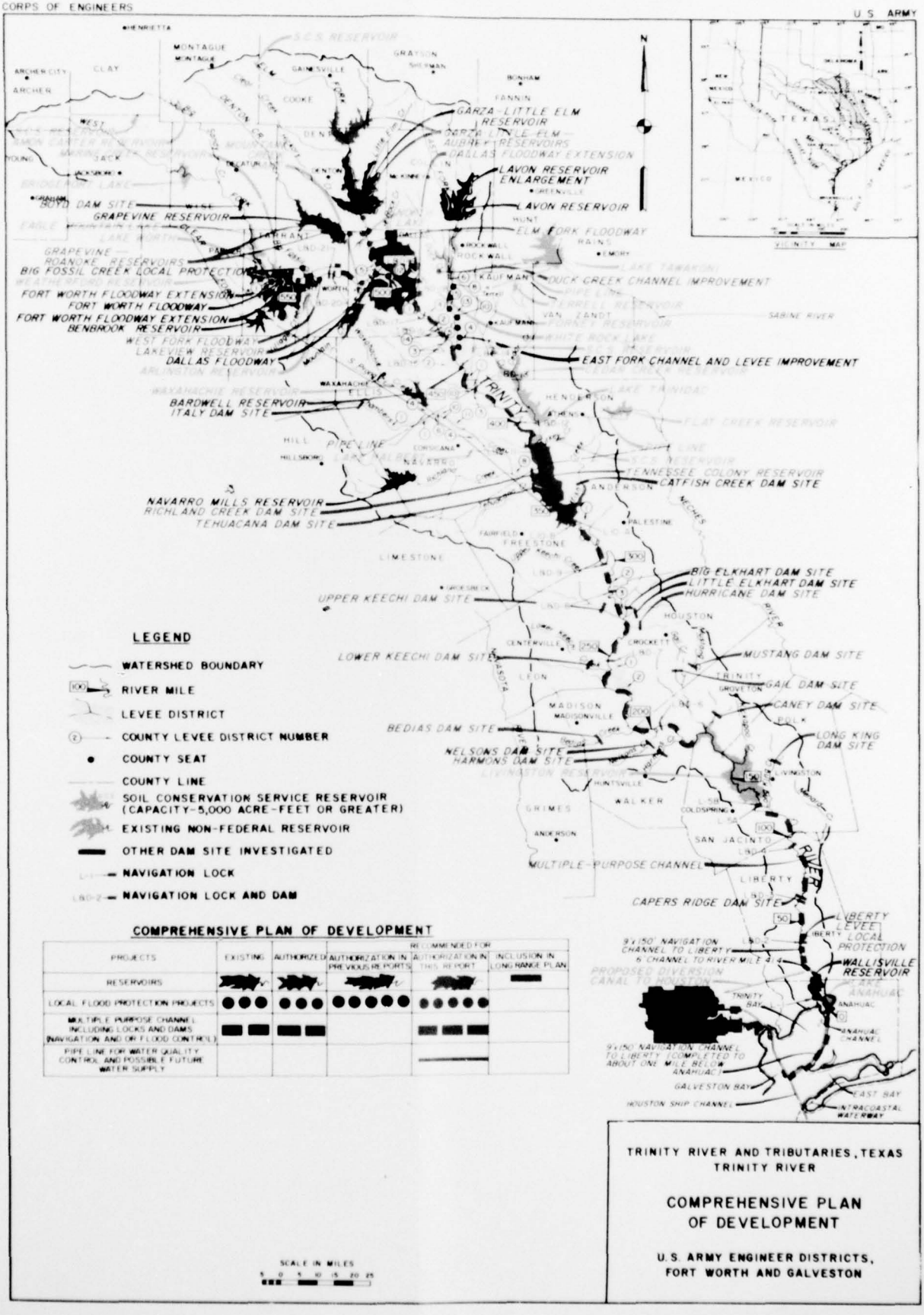
JAMES S. MAXWELL
Lt Col, CE
District Engineer
Galveston District

R. P. West

R. P. WEST
Colonel, CE
District Engineer
Fort Worth District

CORPS OF ENGINEERS

U.S. ARMY



LEGEND

- WATERSHED BOUNDARY
- RIVER MILE
- LEVEE DISTRICT
- COUNTY LEVEE DISTRICT NUMBER
- COUNTY SEAT
- COUNTY LINE
- SOIL CONSERVATION SERVICE RESERVOIR (CAPACITY-5,000 ACRE-FEET OR GREATER)
- EXISTING NON-FEDERAL RESERVOIR
- OTHER DAM SITE INVESTIGATED
- NAVIGATION LOCK
- NAVIGATION LOCK AND DAM

COMPREHENSIVE PLAN OF DEVELOPMENT

PROJECTS	EXISTING	AUTHORIZED	RECOMMENDED FOR AUTHORIZATION IN PREVIOUS REPORTS	RECOMMENDED FOR AUTHORIZATION IN THIS REPORT	INCLUSION IN LONG RANGE PLAN
RESERVOIRS					
LOCAL FLOOD PROTECTION PROJECTS					
MULTIPLE PURPOSE CHANNEL INCLUDING LOCKS AND DAMS (NAVIGATION AND OR FLOOD CONTROL)					
PIPE LINE FOR WATER QUALITY CONTROL AND POSSIBLE FUTURE WATER SUPPLY					

SCALE IN MILES

0 5 10 15 20 25

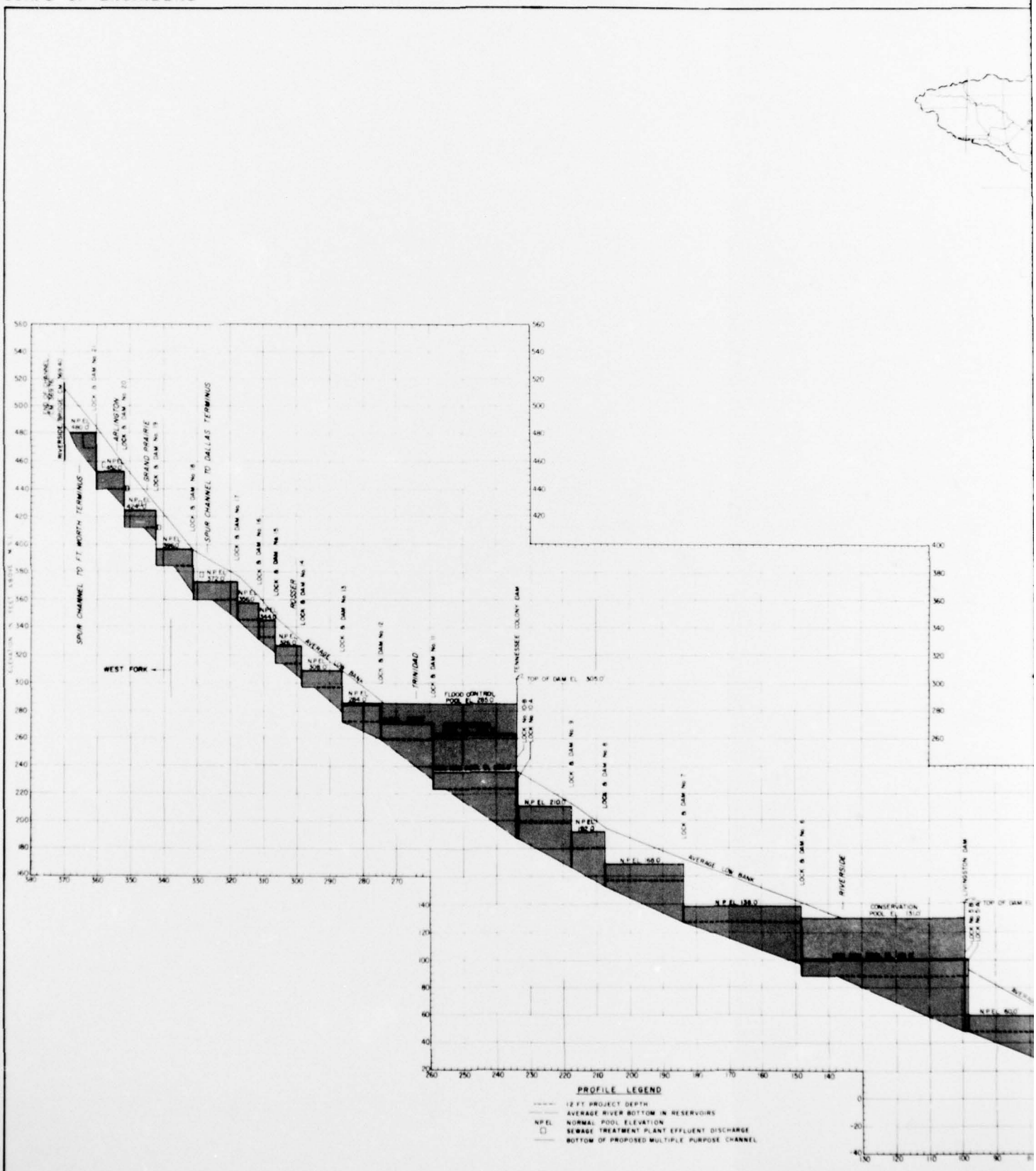
TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER

COMPREHENSIVE PLAN OF DEVELOPMENT

U.S. ARMY ENGINEER DISTRICTS, FORT WORTH AND GALVESTON

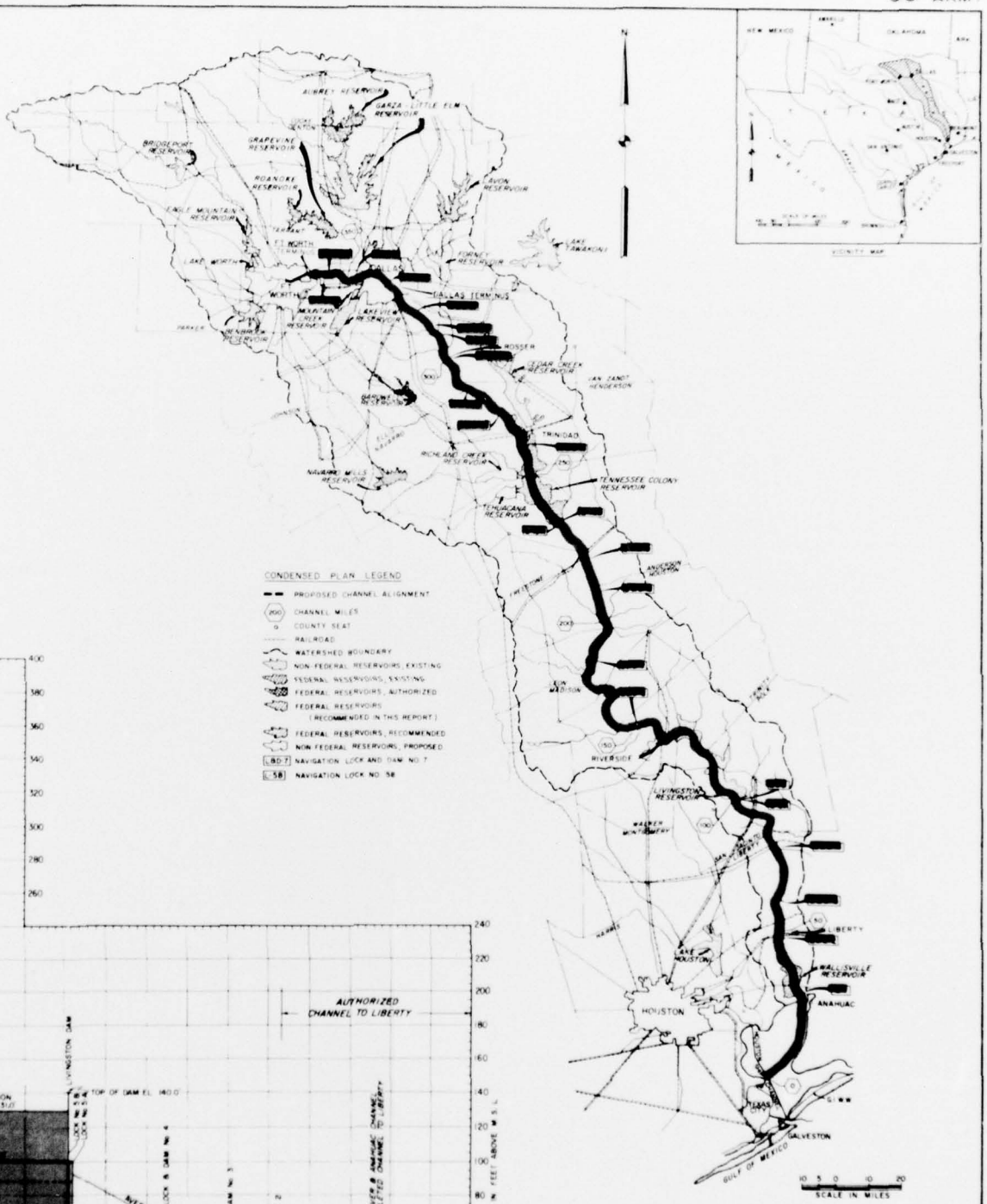
PLATE 1

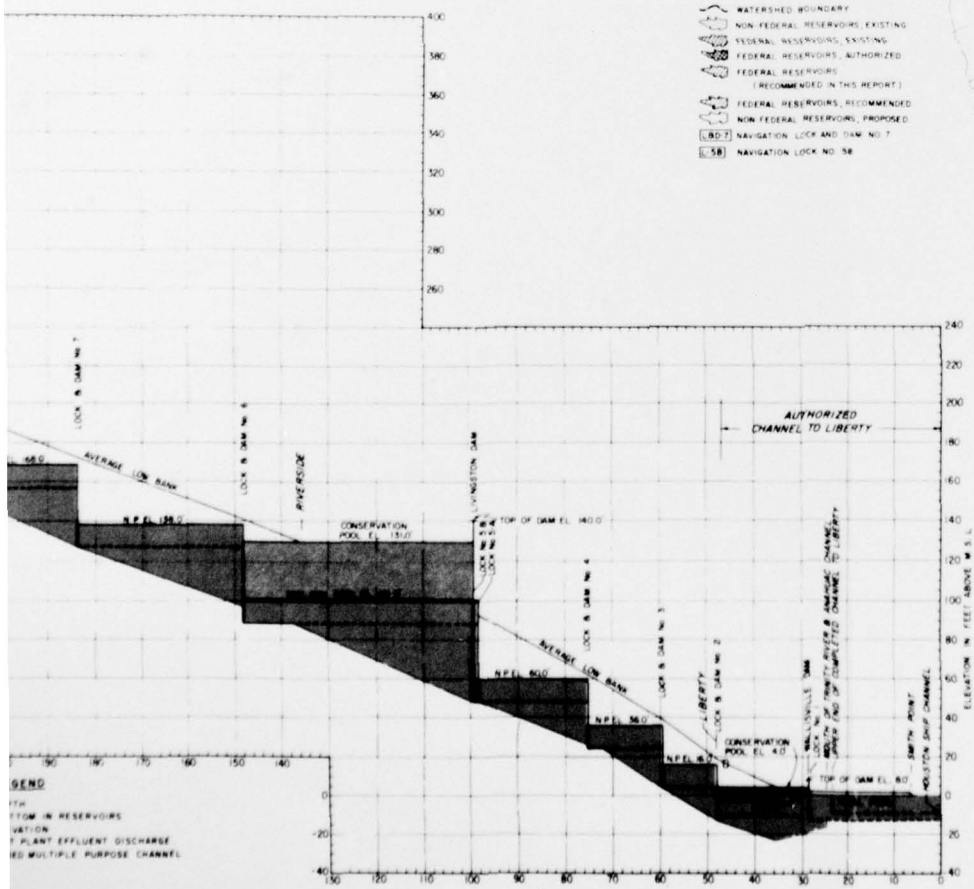
CORPS OF ENGINEERS



MULTIPLE PURPOSE CHANNEL MILES ABOVE THE HOUSTON SHIP CHANNEL

US ARMY





ABOVE THE HOUSTON SHIP CHANNEL

TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER

MULTIPLE PURPOSE CHANNEL

CONDENSED PLAN AND PROFILE

U.S. ARMY ENGINEER DISTRICTS,
FORT WORTH AND GALVESTON

PLATE 2

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